PROCEEDINGS

of the

Indiana Academy of Science

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R. C. CORLEY, Editor

Fifty-Ninth Annual Meeting
BUTLER UNIVERSITY
October 28, 29, and 30, 1943

Copies of the Proceedings may be purchased through the State Library. Indianapolis, Indiana, at $3.00 per volume. All items sent in exchange for the Proceedings and all communications to officers of the Academy, when their names and addresses are not known, should also be sent to the State Library.

Reprints of certain parts of recent volumes of the Proceedings are available for distribution as follows: copies of the constitution and by-laws (Vol. 44), and complete membership list (Vol. 50), may be secured by members elected subsequent to the publication of those volumes; copies of the codified list of duties of officers (Vol. 48) may be secured by officers, divisional chairmen, and chairmen of committees; and copies of the necrology can be supplied to relatives and friends of the deceased members. Inquiries concerning these reprints should be addressed to the Secretary of the Academy, Dr. Winona H. Welch, DePauw University, Greencastle, Indiana.

Reprints of technical papers in recent volumes can often be secured from the authors. They cannot be supplied by the State Library nor by the officers of the Academy.

TABLE OF CONTENTS

Officers and Committees for 1943 v
Program of the Winter Meeting vii
Minutes of the Executive Committee viii
Minutes of the General Session xiii
New Members xv
Past Officers of the Indiana Academy of Science xvii
Indiana Junior Academy of Science xxi
Necrology 1
Presidential Address—THEODOR JUST 14

Bacteriology

Abstracts of papers not published in full 28
L. S. McCLUNG: Recent Developments Concerning the Anaerobic Bacteria and their Activities, with Particular Reference to the Tetanus and Gangrene Organisms 30
L. S. McCLUNG: A Technique for the Production of Immune Sera for *Paramecium aurelia* 47
H. M. POWELL: Epidemic Influenza Vaccine and Antiserum 50
LUCILE J. WEISS: Application of the Electron Microscope to Biological Research 53
C. M. PALMER: History of Bacteriology at Butler University 55
T. G. YUNCKER: History of Bacteriology at DePauw University 57
L. S. McCLUNG: History of Bacteriology at Indiana University 59
ROBERT F. ERVIN, PHILIP C. TREXLER and JAMES A. REYNIERS: History of Bacteriology at the University of Notre Dame 62
P. A. TETRAULT: History of Bacteriology at Purdue University 66

Botany

Abstracts of papers not published in full 72
A. T. GUARD: The Development of the Seed of *Liriodendron tulipifera* L. 75
C. L. PORTER: A Leaf Spot of *Ginkgo biloba* 78
ALBERT W. C. T. HERRE: Lichens Known from Indiana 81
WINONA H. WELCH: Studies in Indiana Bryophytes VI 96
T. G. YUNCKER: Observations on the Presence of Stomata in Some Species of Cuscuta 100
Indiana Plant Distribution Records IV. 1943 105

Chemistry

Abstracts of papers not published in full 116
KENNETH N. CAMPBELL, BARBARA K. CAMPBELL and S. JOELA PATELSKI: p-Methoxyphenylisothiocyanate as a Reagent for the Identification of Amines 119
ED. F. DEGERING: Relative Electronegativity IV. An Empirical Rule as a Teaching Tool 122
FRANK C. MATHERS and ROBERT E. RICKS: Anode Polishing 130
KENNETH WHELAN and FRANK J. WELCHER: A Study of the Grignard Reaction as Applied to Student Preparations 134

Geology and Geography

STEPHEN S. VISHER: Indiana County Contrasts in Population Changes 139

Mathematics

Abstracts of papers not published in full 144

Physics

Abstract of paper not published in full 146

Psychology

Abstracts of papers not published in full 147
FORREST H. KIRKPATRICK and DANIEL J. BOLANOVICH: Directional Tests for Educational Guidance 150

Zoology

Abstracts of papers not published in full 153
R. M. CABLE: The Significance of Studies on the Life Histories of Animal Parasites with Special Reference to Some Digenetic Trematodes 159
GEORGE E. GOULD: Insect Pests of Cucurbit Crops in Indiana 165
WILLIAM HUGH HEADLEE: Human Intestinal Parasite Infections: Further Data Primarily Concerning Indiana Residents 172
JOHN D. MIZELLE: Size Variations in Tetraonchinae 177
B. ELWOOD MONTGOMERY: The Distribution and Relative Seasonal Abundance of the Indiana Species of Agrionidae (Odonata-Zygoptera) 179
JERRE L. NOLAND: An Improved Method for the Determination of the Lethal Temperatures of Insects, with Especial Reference to Studies on *Periplaneta americana* 186
J. P. SCOTT: Social Behavior, Range and Territoriality in Domestic Mice 188

OFFICERS AND COMMITTEES FOR 1943

OFFICERS

President, THEODOR JUST, University of Notre Dame.
Vice-President, C. L. PORTER, Purdue University.
Secretary, WINONA H. WELCH, DePauw University.
Treasurer, W. P. MORGAN, Indiana Central College.
Editor, P. D. EDWARDS, Ball State Teachers College.
Press Secretary, C. M. PALMER, Butler University.
Trustees of Academy Foundation (term 4 years): J. S. WRIGHT, Eli Lilly and Company (term expires 1944), chairman; F. B. WADE, Shortridge High School (term expires 1943).
Committee for Bonding of Trustees: H. L. BRUNER, Butler University, Indianapolis, chairman; W. A. COGSHALL, Indiana University, Bloomington.
Research Grant Committee: A. L. FOLEY, Indiana University (term (term expires 1946); E. G. MAHIN, University of Notre Dame (term expires 1947); JOHN S. WRIGHT, Indianapolis (term expires 1943); M. S. MARKLE, Earlham College (term expires 1944); H. E. ENDERS, Purdue University (term expires 1945); THEODOR JUST, University of Notre Dame (ex officio); WINONA H. WELCH, DePauw University (ex officio).

DIVISIONAL CHAIRMEN

Anthropology, GEORG K. NEUMANN, Indiana University.
Bacteriology, L. S. MCCLUNG, Indiana University.
Botany, A. T. GUARD, Purdue University.
Chemistry, EDWARD HUGHES, Eli Lilly and Company.
Geology and Geography, W. T. BUCKLEY, Indiana University.
Mathematics, W. E. EDINGTON, DePauw University.
Physics, O. H. SMITH, DePauw University.
Psychology, W. A. KERR, R.C.A., Camden, New Jersey.
Zoology, R. M. CABLE, Purdue University.

EXECUTIVE COMMITTEE

(Past Presidents, Officers, Divisional Chairmen, and Chairmen of Standing Committees)

C. A. Behrens, H. L. Bruner, W. T. Buckley, S. Burrage, R. M. Cable, W. A. Cogshall, E. R. Cumings, J. J. Davis, Chas. C. Deam, W. E. Edington, P. D. Edwards, H. E. Enders, A. L. Foley, R. C. Friesner, W. G. Gingery, R. E. Girton, A. T. Guard, Robert Hessler, Edward Hughes, Theodor Just, W. A. Kerr, Eli Lilly, E. G. Mahin, E. S. Martin,

L. S. McClung, M. G. Mellon, W. P. Morgan, G. K. Neumann, C. M. Palmer, F. Payne, N. E. Pearson, C. L. Porter, R. R. Ramsey, O. H. Smith, F. B. Wade, F. N. Wallace, Paul Weatherwax, Winona H. Welch, J. S. Wright, T. G. Yuncker.

BUDGET COMMITTEE

(President, Secretary, Treasurer, Editor, and Chairmen of Committee on Relation of Academy to State, Program Committee, and Library Committee)

P. D. Edwards, R. C. Friesner, W. G. Gingery, Theodor Just, W. P. Morgan, F. N. Wallace, Winona H. Welch.

STANDING COMMITTEES

(Appointed by the President, Chairman of each committee named first)

Auditing: E. S. Martin, K. S. Means.

Biological Survey: N. E. Pearson, W. P. Allyn, H. O. Deay, R. Kriebel, J. D. Mizelle, C. M. Palmer, Dorothy Parker, W. E. Ricker, Winona H. Welch.

Invitations: T. G. Yuncker, G. F. Hennion, J. E. Potzger.

Junior Academy of Science: H. E. Enders, W. P. Allyn, F. J. Breeze, O. B. Christy, M. S. Markle, C. L. Porter, F. B. Wade, M. M. Williams, T. G. Yuncker.

Library: W. G. Gingery, Nellie M. Coats, R. C. Friesner.

Membership: R. E. Girton, G. F. Hennion, R. M. Kriebel, W. E. Martin, J. E. Potzger, Paul Weatherwax.

Nominations: Paul Weatherwax, E. G. Mahin, M. G. Mellon.

Program: R. C. Friesner, R. M. Kriebel, F. A. Loew, Karl Means, N. E. Pearson, J. E. Potzger.

Publication of Proceedings: P. D. Edwards, R. C. Corley, Paul Weatherwax.

Relation of Academy to State: F. N. Wallace, E. Y. Guernsey, Eli Lilly, H. J. Reed, J. S. Wright.

Representative on Council of A.A.A.S.: H. E. Enders.

Resolutions: B. E. Montgomery, F. A. Loew, C. A. Malott.

PROGRAM OF THE WINTER MEETING

BUTLER UNIVERSITY

October 28-30, 1943

THURSDAY, OCTOBER 28

7:30 P. M.

Meeting of the Executive Committee

FRIDAY, OCTOBER 29

9:30 A. M. General Session

Address of Welcome. President M. O. Ross, Butler University.

Response. President Theodor Just.

Necrology. Will E. Edington, DePauw University.

"Indiana Wild Life as Friends of Man." W. P. Allyn, Indiana State Teachers College, Terre Haute.

Exhibit: "Parasitic Diseases," W. H. Headlee, Indiana University School of Medicine, Indianapolis.

11:45 A. M. and 2:30 P. M. Sectional Meetings

6:00 P. M. Annual Dinner

Business Session.

President's Address. "The Rates of Evolutionary Progress," President Theodor Just, University of Notre Dame.

SATURDAY, OCTOBER 30

9:00 A. M.

Taxonomists Meeting

Entomologists Meeting

MINUTES OF THE EXECUTIVE COMMITTEE

INDIANAPOLIS, October 28, 1943

The Executive Committee was called to order by President Just at 8:00 p. m. in Parlor E of the Lincoln Hotel. The reports of officers and committee representatives were presented and accepted as follows:

Academy Trustee. Report of John S. Wright, Frank B. Wade, and W. P. Morgan, Trustees of the Foundation Fund, Indiana Academy of Science, for the year 1942-1943.

Balance from the previous year	$1,220.48
Total receipts	257.14
Total	$1,477.62
Expenditures (for $1,000 Series G, U. S. Treasury Bond)	1,000.00
Balance in Indiana National Bank savings account	$477.62

Assets in the Fund as of October 28, 1943

Five $1,000 U. S. Savings Bonds, Series D—at cost	$3,750.00
Three $1,000 U. S. Savings Bonds, Series G—at cost	3,000.00
Federal Farm Loan and Farm Mortgage Bonds—at par	2,500.00
One $100 U. S. Treasury Bond, 4¼%—at par	100.00
One $100 U. S. Treasury Bond, 3⅛%—at par	100.00
Two $100 Muncie Masonic Temple Assn. Bond—at par	200.00
Six shares Standard Oil Indiana common stock—at par	150.00
Total at par or cost	$9,800.00

After the reading of the report of the Academy Trustees by F. B. Wade, the following resolution was read by John S. Wright.

Whereas the Research Foundation Fund of the Indiana Academy of Science has grown from a few hundred dollars, to approximately ten thousand dollars in a few years; and

Whereas it is specified in the terms of the organization of the Research Foundation Fund that the principal shall be held in trust and invested in accordance with the laws of the State of Indiana governing the reserves of Life Insurance Companies:

BE IT RESOLVED that the Trustees be granted authority to contract with a long-established Trust Company to act as custodian and as co-trustee of the Foundation Fund of the Indiana Academy of Science.

Auditing Committee. E. S. Martin stated that the accounts of the Academy Trustees and the Treasurer are in perfect condition.

Treasurer. W. P. Morgan presented a tentative financial report for the period from January 1 to October 1, 1943. His final report, approved by the Auditing Committee at the end of the year, follows:

Receipts

Balance on hand January 1, 1943	$729.32	
Dues and initiation fees	843.00	
A.A.A.S. refund for research grants	142.00	
Designated gift	300.00	
Publications sold by librarian	15.18	
Authors' reprints Vol. No. 51	22.82	
		$2,052.32

Disbursements

1—Program Committee	$ 90.52		
2—Editor	200.00		
3—Expenses of Secretary	58.04		
4—Expenses of Treasurer	91.80		
5—Mailing Proceedings	35.36		
6—Stationery	30.64		
7—Refund expenses of officers	3.95		
8—Junior Academy Bulletins	20.00		
9—Safety Box and Surety Bonds	31.00		
10—Research Grants: Dr. Mullison	25.00*		
11—Cost of reprints	unpaid		
12—Balance on Proceedings	unpaid		
13—Books purchased for Library	50.55		
14—Returned checks from members	2.00		
		$ 638.86	
Balance on hand		1,413.46	
			$2,052.32

* Check drawn for $75.00 in payment of research grant to Dr. A. L. Foley had not cleared when back statement was prepared.

(Signed) W. P. MORGAN, *Treasurer*,

(Signed) ERSIE S. MARTIN } *Auditors.*
(Signed) KARL S. MEANS }

Bonding Committee. H. L. Bruner reported that the cost of bonding, twenty-five dollars, had been paid to the Hartford Accident and Indemnity Company, Indianapolis, Indiana.

Editor and Publication of Proceedings. P. D. Edwards reported that page proof was completed in time for delivery of the *Proceedings* in June but the printing had been delayed because of paper shortage. Delivery is expected in November.

Number of pages in volume 52	258
Number of copies cloth bound	1,000
Number of copies paper bound	600
Number of reprints	11,400
Cost of engraving, printing, and binding	$1,500.00
Postage and editorial expense	$200.00

Research Grant. One application had been received by the committee, that of Dr. Arthur L. Foley. A grant of $150.00 from the A.A.A.S. research fund to the Academy was made to Dr. Foley for the purchase of necessary apparatus for his experiments in surface tension. Upon the

completion of the study the materials purchased with the grant are to become the property of the Indiana Academy of Science.

Biological Survey. N. E. Pearson had no report. Committee's work had been greatly decreased because of restriction on travel due to war.

Fifty-Year Index. A progress report was made by R. C. Friesner and G. H. Smith. J. S. Wright commented concerning the value of the Index to libraries and scientists.

Library Committee. W. G. Gingery presented the report of Nellie M. Coats, Academy Librarian.

Shipments of Indiana Academy of Science Proceedings for societies and institutions in Great Britain, India, New Zealand, New South Wales, Portugal, Queensland, South Africa, South Australia, Tasmania, Victoria, Western Australia, and all countries in the western hemisphere have been forwarded through the Smithsonian International Exchange Service since January, 1943. Copies of *Proceedings* intended for societies and institutions not included in this geographic range are being held in Indianapolis for shipment later. Publications have been received from the following locations outside the continental U. S. A.: Argentina, Australia, Brazil, Canada, Chile, China, Cuba, Ecuador, England, Haiti, Hawaii, Ireland, Mexico, Paraguay, Peru, Russia, Scotland, South Africa, Switzerland, Uruguay, and Venezuela.

During the year 41 new serial titles have been added, and 182 volumes have been bound at a cost of $215.30. The budget committee also supplied an additional fund of $60.00 with which to purchase fugitive items missing from the serial files.

The files of the *Proceedings* available for exchange were increased by a gift of 25 volumes from Wabash College and 161 volumes from Indiana University. It will be greatly appreciated if a member having any duplicate copies will return them to this exchange file at the State Library.

The use of the Academy Library has increased since the listing of its titles in the Union list of serials in Indiana Libraries and in the H. W. Wilson Company Union list for the U. S. A.

Press Secretary. C. M. Palmer reported that news releases for the 1942 meeting were sent out with the co-operation of the Publicity Office of the University of Notre Dame and for the 1943 meeting with the aid of the Publicity Office of Butler University. Science Service and Science publish articles on the meetings of the Indiana Academy. The abstracts sent in by authors of papers to be presented in the Sectional Meetings were of considerable aid in the preparation of the news releases.

Membership. R. E. Girton presented a tentative report as election of members occurs at dinner meeting.

Junior Academy of Science. H. E. Enders announced that the Indiana Junior Academy of Science consists of forty-three clubs, some of which

have as many as six sections in a single high school, and that, because of travel restrictions, the clubs have voted to cancel their formal meeting for this year.

However, the Science Clubs of Indianapolis have arranged to hold a sectional meeting and to provide a program and exhibits at Butler University, Saturday morning, October 30. The high schools participating are Manual Training, Shortridge, Arsenal Technical, Crispus Attucks, Washington, Broadripple, and Thomas Carr Howe.

Relation of Academy to State. F. N. Wallace reported that the Legislature granted the Academy $1500.00 for the publication of the *Proceedings* and for binding the reports in the Academy Library.

Relation of Academy to A.A.A.S. No meeting of A.A.A.S. was held in 1942.

Nominations. Dr. Weatherwax presented the name of Dr. Ray F. Dawson, Princeton University, for election as Fellow.

Invitations. Pres. Just appointed Chairman, T. G. Yuncker, G. F. Hennion, J. E. Potzger.

Resolutions. Pres. Just appointed Chairman, B. E. Montgomery, F. A. Loew, C. A. Malott.

Old Business. The committee report concerning the affiliation of the Indiana Branch of the Society of American Bacteriologists with the Bacteriology Section of the Indiana Academy of Science was accepted favorably. Committee: Chairman, C. G. Culbertson, L. S. McClung, H. M. Powell, T. G. Yuncker.

New Business. John S. Wright was elected to succeed himself on research Grant Committee, his new term expiring in 1948.

F. B. Wade was elected to succeed himself as Academy Foundation Trustee, his new term expiring in 1947.

H. L. Bruner, Chairman, and W. A. Cogshall were elected to continue as members of the Committee for Bonding Trustees.

A decision was made that in instances of Academy Sections having no programs, the Sectional Chairman is to continue as Chairman of that section the following year.

A recommendation was made that a chairman of a committee be appointed for the consideration of plans for a History of Science in Indiana, including the biographies of Indiana scientists. Said committee is to consist of a chairman, and a member from each of the sections of the Academy. The most feasible plan is to be presented at the next meeting of the Academy.

A committee is to be appointed to make recommendations for the procedure whereby any scientific organization of Indiana may affiliate with the Indiana Academy of Science. These recommendations are to be presented for consideration of the Academy at its next meeting.

John S. Wright read the following resolution to be sent by night letter to the Izaak Walton League of America.

"Lew Hofmann, President
The Izaak Walton League of America
Terre Haute House
Terre Haute, Indiana

The Indiana Academy of Science now in session at Butler University, Indianapolis, notes with satisfaction that you are considering conservation of our natural resources. Please accept our greetings and best wishes for a profitable discussion of problems in which we are mutually interested.

Indiana Academy of Science
President Just

Prof. C. O. Lee was elected to solicit papers, concerning the history of the different fields of science, which are to be presented at the 1944 Academy meeting in a section on the History of Science.

The Secretary was instructed to send greetings and wishes for speedy recovery from the Academy to S. S. Visher, E. R. Smith, and Chas. M. Ek.

Adjournment, 10:00 p. m.

MINUTES OF THE GENERAL SESSION

BUTLER UNIVERSITY, October 29, 1943

President M. O. Ross, Butler University, delivered the Address of Welcome. President Just responded in behalf of the Academy.

W. E. Edington presented the Necrology.

Minutes of the Executive Committee meeting of Oct. 28, 1943, were read by the secretary and approved by the Academy.

W. P. Allyn gave a very interesting discussion concerning, "Indiana wild life as friends of man," illustrated by kodachrome slides.

Following the annual dinner in the Lincoln Room of the Lincoln Hotel, R. E. Girton presented forty-two applications for membership. The secretary was instructed to cast an unanimous ballot for the forty-two applicants.

Paul Weatherwax read the nominations of the committee as follows: *President*, C. A. Malott, Indiana University; *Vice-President*, R. B. Abbott, Purdue University; *Secretary*, Winona H. Welch, DePauw University; *Treasurer*, W. P. Morgan, Indiana Central College; *Editor*, R. C. Corley, Purdue University; and *Press Secretary*, C. M. Palmer, Butler University.

The Divisional Chairmen elected in the sectional meetings for 1944 were announced as follows: *Anthropology*, George K. Neumann, Indiana University; *Bacteriology*, Lyle A. Weed, Indiana University Medical Center, C. M. Palmer, Butler University, Vice-Chairman; *Botany*, Benjamin H. Smith, Indiana State Teachers College; *Chemistry*, F. B. Wade, Shortridge High School, Indianapolis; *Geology & Geography*, A. H. Meyer, Valparaiso University; *Mathematics*, Paul M. Pepper, University of Notre Dame; *Physics*, Mason E. Hufford, Indiana University; *Psychology*, H. H. Remmers, Purdue University; and *Zoology*, W. H. Headlee, Indiana University School of Medicine.

T. G. Yuncker announced that the Committee on Invitations had accepted the invitation of Butler University for the 1944 Fall Meeting of the Academy.

B. E. Montgomery expressed on behalf of the Academy its sincere appreciation and thanks to the Program Committee under the leadership of Ray C. Friesner, to Pres. M. O. Ross of Butler University as well as the administration and staff, and to the manager of the Lincoln Hotel for their contributions in numerous ways to the success of the 1943 meeting of the Academy. Theodor Just, retiring president, delivered a scholarly address on "The rates of evolutionary processes."

The Academy recognized John S. Wright and Arthur L. Foley for their attendance of the meetings for fifty years and for their active interest in the affairs of the Academy throughout the entire period. John S. Wright became a member of the Indiana Academy of Science in 1893 and a Fellow in 1894, and Arthur L. Foley a member in 1894 and a Fellow in 1897.

The 59th annual* meeting of the Indiana Academy of Science, with a general attendance of 171 and a dinner attendance of 86, was adjourned.

WINONA H. WELCH, Secretary

TAXONOMISTS MEETING

Chairman: SCOTT MCCOY, Dir., Holliday Park

The Plant Taxonomists held their meeting on Saturday morning at The John H. Holliday Park Botanical Garden. John E. Seybert, Botanist, Eli Lilly Company, was elected chairman for 1944.

ENTOMOLOGISTS MEETING

Chairman: B. E. MONTGOMERY, Purdue University

The Entomologists held their meeting in Jordan Hall, Butler University. Ralph Morris, Assistant State Entomologist, was elected chairman for 1944.

* No spring meeting was held during 1943.

NEW MEMBERS

Amstutz, Mr. Noah S., Chicago Road, Valparaiso, Ind.
Anderson, Mr. Hanson H., Dept. of Math. Arsenal Tech., Indianapolis, Ind.
Beal, Mrs. Juna L., Dept. of Math., Butler Univ., Indianapolis, Ind.
Bedient, Dr. Harold A., Dept. of Chemistry, Evansville College, Evansville, Ind.
Blackford, Sister John Joseph, 3600 Cold Springs Road, Indianapolis 44, Ind.
Bloom, Mr. William W., Biology Dept., Valparaiso U., Valparaiso, Ind.
Brodie, Mr. Donald C., Pharmacy Bldg., Purdue U., Lafayette, Ind.
Bushong, Miss Mary Ellen, Dept. of Chemistry, W. Lafayette High School, W. Lafayette, Ind.
Cross, Dr. Aureal T., Dept. of Biology, U. Notre Dame, Notre Dame, Ind.
Dannin, Dr. Albert Gurney, 505 Guaranty Bldg., Indianapolis, Ind.
Demeter, Miss Margaret, 2707 E. Thirty-first, Lorain, Ohio
Everly, Mr. Ray Thomas, Purdue Agri. Exper. Sta., W. Lafayette, Ind.
Griffin, Mr. Paul M., 2004 W. Jackscon, Muncie, Ind.
Haynes, Dr. Edith, Dept. of Bacteriology, Indiana U. Medical Center, Indianapolis, Ind.
Kuehrmann, Mr. Otto W., 3332 N. Pennsylvania, Indianapolis 5, Ind.
Lee, Mr. Mordie B., 2445 E. 40th St., Indianapolis, Ind.
Lefler, Mr. Ralph W., 306 Russell, W. Lafayette, Ind.
Lingeman, Mr. Roger S., 224 N. Talley Ave., Muncie, Ind.
Luria, Dr. S. E., Bacteriology Dept., Ind. U., Bloomington, Ind.
Marks, Mr. Charles, 4115 Graceland Ave., Indianapolis, Ind.
Moulton, Mr. Benjamin, Butler U., Dept. of Geography, Indianapolis, Ind.
Newsum, Mr. Noble, R. R. 16, Box 390, Indianapolis, Ind.
Plunkett, Dr. Donald J., 926 N. Notre Dame Ave., South Bend, Ind.
Prentice, Prof. Burr N., 20 Waldron St., W. Lafayette, Ind.
Rogers, Miss Helen Margaret, 311 Waldron St., W. Lafayette, Ind.
Schlosberg, Mr. Morris, P. O. Box 606, W. Lafayette, Ind.
Scott, Miss Dorothy Lillian, Botany in Biology Dept., Purdue U., W. Lafayette, Ind.
Shadinger, Dr. G. H., Dept. of Chemistry, Butler U., Indianapolis, Ind.
Udine, Mr. E. J., Purdue Agri. Exp. Station, W. Lafayette, Ind.
Vance, Mr. Arlo M., Box 606, W. Lafayette, Ind.
Vance, Dr. Charles B., Dept. of Physics, Evansville College, Evansville, Ind.
Vogel Jr., Dr. Howard H., Dept. of Zoology, Wabash College, Crawfordsville, Ind.
Wallace, Dr. Atwell Milton, Dept. of Biology, Anderson College, Anderson, Ind.
Ward, Dr. Helen L., School of Medicine, I. U., Indianapolis, Ind.
Whelan, Mr. Kenneth, 122 E. Michigan, Indianapolis, Ind.
Wilson, Miss Mona Jane, Dept. of Chemistry, Shortridge High School, Indianapolis, Ind.

Wright, Mr. Howard F., 2152 N. Meridian, No. 302, Indianapolis, Ind.
Wright, Dr. Jonathan W., Forestry Dept., Purdue Univ., W. Lafayette, Ind.
Wuest, Rev. Albert A., Dept. of Chemistry, St. Joseph's College, Collegeville, Ind.
Zangerl, Dr. Rainer, Dept. of Biology, U. Notre Dame, Notre Dame, Ind.
Zanolar, Rev. Alfred J., Math. Dept., St. Joseph's College, Collegeville, Ind.
Zuck, Dr. Robert K., Dept. of Biology, Evansville College, Evansville, Ind.

PAST OFFICERS OF THE INDIANA ACADEMY OF SCIENCE

Year	President	Vice-President	Secretary
1886[1]	*David S. Jordan		*Amos W. Butler
1887	*John M. Coulter		*Amos W. Butler
1888	*J. P. D. John		*Amos W. Butler
1889	*J. C. Branner		*Amos W. Butler
1890	*T. C. Mendenhall		*Amos W. Butler
1891	*O. P. Hay		*Amos W. Butler
1892	*J. L. Campbell	*J. C. Arthur *W. A. Noyes	*Amos W. Butler
1893	*J. C. Arthur	*W. A. Noyes	*Amos W. Butler
1894	*W. A. Noyes	*Amos W. Butler	*C. A. Waldo
1895	*Amos W. Butler	*Stanley Coulter	John S. Wright
1896	*Stanley Coulter	*Thomas Gray	John S. Wright
1897	*Thomas Gray	*C. A. Waldo	John S. Wright
1898	*C. A. Waldo	*C. H. Eigenmann	John S. Wright
1899	*C. H. Eigenmann	*D. W. Dennis	John S. Wright
1900	*D. W. Dennis	*M. B. Thomas	John S. Wright
1901	*M. B. Thomas	*P. S. Baker	John S. Wright
1902	*Harvey W. Wiley	*W. S. Blatchley	John S. Wright
1903	*W. S. Blatchley	*C. L. Mees	John S. Wright
1904	*C. L. Mees	*Glenn Culbertson	John S. Wright
1905	John S. Wright	*Robert Hessler	L. B. McMullen
1906	*Robert Hessler	*D. M. Mottier	L. B. McMullen
1907	*D. M. Mottier	*Glenn Culbertson	L. B. McMullen
1908	*Glenn Culbertson	A. L. Foley	*J. H. Ransom
1909	A. L. Foley	*P. N. Evans	*J. H. Ransom
1910	*P. N. Evans	*C. R. Dryer	G. W. Benton
1911	*C. R. Dryer	*D. W. Dennis	*A. J. Bigney
1912	*J. P. Naylor	*D. Bodine	*A. J. Bigney
1913	*D. Bodine	Severance Burrage	*A. J. Bigney
1914	Severance Burrage	A. L. Foley	*A. J. Bigney
1915	W. A. Cogshall	*W. A. McBeth	*A. J. Bigney
1916	*A. J. Bigney	*Amos W. Butler	H. E. Enders
1917	W. J. Moenkhaus	*E. Morrison	H. E. Enders
1918	E. B. Williamson	*C. Stoltz	H. E. Enders
1919	E. B. Williamson	*C. Stoltz	H. E. Enders
1920	H. L. Bruner	*W. A. McBeth	H. E. Enders
1921	H. E. Enders	*F. M. Andrews	Walter N. Hess

[1] The first meeting of the Academy was held December 29, 1885. Dr. John P. D. John acted as temporary chairman. David Starr Jordan was chosen as the first president.

* Deceased.

YEAR	PRESIDENT	VICE-PRESIDENT	SECRETARY
1922	*F. M. Andrews	C. A. Behrens	Walter N. Hess
1923	C. A. Behrens	F. Payne	Walter N. Hess
1924	C. C. Deam	*C. M. Smith	Flora Anderson
1925	E. R. Cumings	*C. Stoltz	Flora Anderson
1926	*W. M. Blanchard	*L. J. Rettger	R. C. Friesner
1927	F. B. Wade	*F. J. Breeze	R. C. Friesner
1928	E. G. Mahin	Walter N. Hess	R. C. Friesner
1929	*L. J. Rettger	*J. A. Nieuwland	R. C. Friesner
1930	Rolla R. Ramsey	M. S. Markle	R. C. Friesner
1931	J. J. Davis	T. G. Yuncker	R. C. Friesner
1932	F. Payne	Richard Lieber	R. C. Friesner
1933	*Marcus W. Lyon, Jr.	M. S. Markle	R. C. Friesner
1934	*J.A. Nieuwland	*M. L. Fisher	R. C. Friesner
1935	*Will Scott	W. E. Edington	R. C. Friesner
1936	R. C. Friesner	Edward Kintner	*L. A. Test
1937	W. E. Edington	C. A. Malott	*L. A. Test
1938	Eli Lilly	T. G. Yuncker	W. P. Allyn
1939	T. G. Yuncker	*L. A. Test	W. P. Allyn
1940	Frank Wallace	S. S. Visher	W. P. Allyn
1941	Paul Weatherwax	E. F. Degering	Winona H. Welch
1942	M. G. Mellon	Theodor Just	Winona H. Welch
1943	Theodor Just	C. L. Porter	Winona H. Welch
1944	C. A. Malott	R. B. Abbott	Winona H. Welch

YEAR	TREASURER	EDITOR[2]	PRESS SECRETARY
1886	*O. P. Jenkins		
1887	*O. P. Jenkins		
1888	*O. P. Jenkins		
1889	*O. P. Jenkins		
1890	*O. P. Jenkins		
1891	*O. P. Jenkins	*O. P. Hay *C. A. Waldo *J. M. Coulter	
1892	*C. A. Waldo	*O. P. Hay *C. A. Waldo *J. M. Coulter	
1893	*C. A. Waldo	*O. P. Hay *C. A. Waldo *J. M. Coulter	
1894	*W. P. Shannon	*W. A. Noyes *C. A. Waldo W. W. Norman	

[2] The editor is listed with the officers of the year although he edits the *Proceedings* of the preceding year.

* Deceased.

YEAR	TREASURER	EDITOR[2]	PRESS SECRETARY
1895	*W. P. Shannon	*Stanley Coulter	
		*J. C. Arthur	
		*R. E. Call	
		*A. W. Duff	
1896	*W. P. Shannon	*C. A. Waldo	
1897	*W. P. Shannon	*C. A. Waldo	
1898	*J. T. Scovell	*C. A. Waldo	G. W. Benton
1899	*J. T. Scovell	G. W. Benton	G. W. Benton
1900	*J. T. Scovell	G. W. Benton	G. W. Benton
1901	*J. T. Scovell	G. W. Benton	G. W. Benton
1902	*J. T. Scovell	*D. Bodine	G. W. Benton
1903	*W. A. McBeth	*D. Bodine	G. A. Abbott
1904	*W. A. McBeth	W. J. Karslake	G. A. Abbott
1905	*W. A. McBeth	*D. Bodine	G. A. Abbott
1906	*W. A. McBeth	E. G. Martin	C. R. Clark
1907	*W. A. McBeth	A. L. Foley	G. A. Abbott
1908	*W. A. McBeth	L. B. McMullen	G. A. Abbott
1909	*W. A. McBeth	H. L. Bruner	G. A. Abbott
1910	W. J. Moenkhaus	H. L. Bruner	J. W. Woodhams
1911	W. J. Moenkhaus	*L. J. Rettger	Milo H. Stuart
1912	W. J. Moenkhaus	*L. J. Rettger	Milo H. Stuart
1913	W. J. Moenkhaus	C. C. Deam	F. B. Wade
1914	W. A. Cogshall	H. E. Barnard	F. B. Wade
1915	*W. M. Blanchard	H. E. Barnard	F. B. Wade
1916	*W. M. Blanchard	H. E. Barnard	F. B. Wade
1917	*W. M. Blanchard	L. F. Bennett	F. B. Wade
1918	*W. M. Blanchard	L. F. Bennett	F. B. Wade
1919	*W. M. Blanchard	L. F. Bennett	F. B. Wade
1920	*W. M. Blanchard	F. Payne	F. B. Wade
1921	*W. M. Blanchard	*F. J. Breeze	F. B. Wade
1922	*W. M. Blanchard	F. Payne	F. B. Wade
1923	*W. M. Blanchard	J. J. Davis	H. F. Dietz
1924	*W. M. Blanchard	J. J. Davis	H. F. Dietz
1925	*W. M. Blanchard	J. J. Davis	H. F. Dietz
1926	*C. M. Smith	J. J. Davis	H. F. Dietz
1927	*M. W. Lyon, Jr.	J. J. Davis	H. F. Dietz
1928	*M. W. Lyon, Jr.	J. J. Davis	H. F. Dietz
1929	*M. W. Lyon, Jr.	Stanley A. Cain	H. F. Dietz
1930	*M. W. Lyon, Jr.	Stanley A. Cain	W. E. Edington
1931	*M. W. Lyon, Jr.	Stanley A. Cain	W. E. Edington
1932	*M. W. Lyon, Jr.	Stanley A. Cain	W. E. Edington
1933	Paul Weatherwax	Stanley A. Cain	W. E. Edington
1934	Paul Weatherwax	Stanley A. Cain	W. E. Edington
1935	W. P. Morgan	Paul Weatherwax	T. R. Johnston

[2] The editor is listed with the officers of the year although he edits the *Proceedings* of the preceding year.

* Deceased.

YEAR	TREASURER	EDITOR[2]	PRESS SECRETARY
1936	W. P. Morgan	Paul Weatherwax	T. R. Johnston
1937	W. P. Morgan	Paul Weatherwax	*M. W. Lyon, Jr.
1938	W. P. Morgan	Paul Weatherwax	W. E. Edington
1939	W. P. Morgan	Paul Weatherwax	W. E. Edington
1940	W. P. Morgan	Paul Weatherwax	W. E. Edington
1941	W. P. Morgan	P. D. Edwards	W. E. Edington
1942	W. P. Morgan	P. D. Edwards	C. M. Palmer
1943	W. P. Morgan	P. D. Edwards	C. M. Palmer
1944	W. P. Morgan	R. C. Corley	C. M. Palmer

INDIANA JUNIOR ACADEMY OF SCIENCE

OFFICERS FOR 1942

President: James Sarasien, Phi-Chem Club, Elmhurst High School, Fort Wayne

Vice-President: Jack Moseley, Greencastle High School.

Secretary: Selma Heaton, Mishawaka High School.

PROGRAM OF THE TWELFTH ANNUAL MEETING

UNIVERSITY OF NOTRE DAME, October 31, 1942

10:00 A. M., Room 216 Chemistry Hall

James Sarasien, President, presiding

"Reaping rewards," Jean Ross, Hammond.

"Science and the war effort," Margaret Clark, Bloomington.

"Anesthesia—history and methods of production," James Smith and Marvin Tomer, South Bend.

"Of an eclipse machine," Jimmy Clay, Bloomington.

"Tooth and its construction," John Tzouandkis, Bloomington.

"The results of a student analysis of crude petroleum," Joan Hendrix, Indianapolis.

"The actions of wasps," Katie Charat, Lew Wallace High School, Gary.

Business session—Election of Officers.

1:00 P. M., Auditorium, Cushing Hall of Engineering

"The autobiography of vanished forests in our lake sediments," Dr. John E. Potzger, Department of Botany, Butler University, Indianapolis.

"Indiana state parks." Illustrated talks by members of the Junior Walton League, South Bend.

"Elementary endocrinology in the Junior Academy of Science," Eileen Brock, Elkhart.

"Medicinal substances found in a chemist's laboratory," Robert Ludlow of Indianapolis.

"Report of progress," Dean Enders, State Sponsor.

EXHIBITS

Mishawaka High School	
Wind Tunnel	Don German
Ultra Violet Light (Demonstration)	Bruce Caldwell
Synthetic and Natural Rubber	Chemistry Section
Working Model of Geyser	Physical Geography Section
Library of Autographs of Present Day Scientists	Biology Section
Elkhart	
Elementary Endocrinology in the Junior Academy of Science	Eileen Brock
South Bend (Central H. S.) Photography Club	
Enlarged micrographs 8	
Aerial Views 3	
	Robert Gibson
Photograph of Moon 1	Richard Matternowski
General Views 3	
Bloomington	
Demonstration of an Eclipse Machine	Jimmy Clay
Demonstration of a Tooth and its Construction	John Tzouandkis
Indianapolis (Technical H. S.) Chemistry Club	
The Results of a Student's Analysis of Petroleum	Joan Hendrix
The Products Obtained from the Manufacture of Commercial Gas	Wilbur Oakley
Medicinals Founds in a Chemistry Lab.	Robert Ludlow
How to Silver a Mirror	Marion Maple

MINUTES

The twelfth annual meeting of the Indiana Junior Academy of Science was held Saturday, October 31, 1942 in Room 216, Chemistry Hall, Notre Dame University, South Bend, Indiana.

Dr. Howard E. Enders, Dean of the School of Science of Purdue University and State Sponsor of the Junior Academy of Science gave a word of greeting and introduced the President, James Sarasien of the Phi-Chem Club, Elmhurst High School, Fort Wayne; Jack Mosely, Vice President, Greencastle; and Selma Heaton, Secretary, of the Mishawaka High School.

The president opened the meeting by calling for the minutes of the previous meeting. They were read and approved. The roll call was taken. Eighteen of the 45 clubs of the Indiana Junior Academy of Science were represented at the meeting.

Jean Ross of Hammond, selected last year as the "Best Girl", brought out in her speech, "Reaping Awards" that success can be attained only through putting one's heart into one's work. She described her trip to

Dallas, Texas, during the 1941 Christmas holidays, to attend the 110th annual convention of the American Association for the Advancement of Science. In July, Miss Ross had the further honor of being chosen one of the forty winners in the national competitive Science Talent Search. She told of her trip to Washington, D. C., and the winning of a scholarship. In closing, she urged the members not to give up hope if they were delayed or discouraged but to strive for the best and to expect the best.

The president then introduced James Smith and Marvin Tomer, South Bend, because their demonstration was ready. A demonstration was given on the history of anesthesia and the methods of its production.

The three speakers from Bloomington were unable to come because of transportation difficulties.

Miss Joan Hendrix gave the results of the analysis of crude petroleum that she and Burden Southern, Indianapolis, had done. The crude oil was from Oklahoma. The crude oil was heated and vapors condensed. Gasoline was obtained at the boiling point of 100° C, and 170° a mixture of high test gasoline came over. From 170° to 250° kerosene was obtained. At 250° to 310° the distillate was fuel oil. Light lubricating oil was produced next at 320° to 360°. Heavy lubricating oil came after the temperature 360°, but since the thermometer was calibrated only to 360°, the temperature was not recorded. Asphalt and petroleum coke was the residue left in the still.

An interesting talk upon "The Actions of Wasps" was given by Miss Katie Charat, Lew Wallace High School, Gary, Indiana.

Dean Enders made a few announcements.

The following new officers were elected for next year:

President—Mary Ann Stout, High School, Elkhart

Vice President—Lloyd Nevel, High School, Mishawaka

Secretary—James Smith, Central High School, South Bend

The new Council member elected for 1942 to 1947 was H. H. Michaud of the North Side High School, Fort Wayne, to succeed Lola Lemon, Gary, whose term expires with the close of the present meeting.

The members were invited to the University Cafeteria for lunch. The meeting adjourned for luncheon.

The afternoon session was held in the auditorium of Cushing Hall of Engineering.

Dr. Howard E. Enders introduced Professor John E. Potzger, Department of Botany, Butler University, Indianapolis. He gave a very interesting illustrated discussion upon the subject of "The Autobiography of Vanished Forests in Our Lake Sediments" with the use of boring and sampling equipment that was employed to make the findings.

Five members of the Junior Walton League, South Bend, Indiana, gave illustrated talks, with slides in color of Indiana State Parks. Ralph Craver was the general chairman of the discussion. The speakers and their subjects were "Pokagon State Park" by Helen Meers; "Spring Mill" by Franklin McKay; "Brown County State Park" by Elaine

Newyard; "Jasper State Park" by Lewis Omundsen; "Indiana Dunes" by Betty Sovinski.

Miss Eileen Brock discussed five of the endocrine glands that she had dissected out of animal bodies: the pituitary, thyroid, thymus, islands of Langerhans in the pancreas, and adrenals. She told a few of the diseases produced by their absence, and indicated locations of these glands on an illustrative model that she displayed. She explained that the most valuable service she has learned from her work is to think for herself.

"Medicinal Substances Found in a Chemist's Laboratory" was discussed by Robert Ludlow.

The Chemistry Club of Technical High School has been added to the Indiana Junior Academy of Science. The number of active member clubs is thirty-eight.

EILEEN BROCK

HAZEN KEYSER

The Council chose Eileen Brock of Elkhart and Hazen Keyser of Fort Wayne as the "Best Girl" and "Best Boy", respectively to recommend for Honorary Membership in the American Association for the Advancement of Science.

The meeting adjourned 2:30 P. M.

SELMA HEATON, *Secretary*

NECROLOGY

WILL E. EDINGTON, DePauw University

HOMER FRANCIS BLACK

Peru, Indiana — Valparaiso, Indiana
August 23, 1874 — April 14, 1942

Probably one of the greatest rewards that can come to a teacher after long years of association with a college is to become so identified with the college that its alumni hold him in the greatest affection and immediately seek him out on their return. Such a teacher was Homer F. Black, who on his retirement in 1941 from Chicago Technical College, after twenty-two years of service, was greatly beloved by the Graduates of that college. He had won this respect and admiration through his unselfish interest in his students and his unusual ability to impart knowledge.

Professor Black was born near Peru, Indiana, but received his elementary and high school education at LaFontaine in Wabash county. He began teaching at the age of nineteen and taught in the public schools at Lincolnville, LaFontaine, Urbana and Roann, spending his vacations in attendance at the Indiana State Normal School at Terre Haute from which he grduated in 1901. He then attended Purdue University and in 1902 took charge of the manual training at Valparaiso University, remaining there until 1918. During this time he attended several summer sessions at Bradley Polytechnic Institute and the University of Chicago, and received his A.B. degree from Valparaiso in 1916. He left Valparaiso to become a draftsman in the tin mills at Gary and to teach mathematics in the evening schools, but the following year he began his work with Chicago Technical College where he remained until his retirement, teaching mathematics, physics and engineering courses.

Deeply interested in astronomy he possessed his own telescope which he shared with his friends and students and he derived great pleasure in pointing out celestial objects and explaining their nature and motions. He was also a devotee of chess. While his chief interest was in science he nevertheless read widely which enabled him to make his teaching more effective and interesting.

Professor Black joined the Indiana Academy of Science in 1916 but was seldom able to attend its meetings. He passed away less than a year after his retirement after having completed almost a half century of teaching.

WILLIAM MARTIN BLANCHARD

Hertford, North Carolina — Greencastle, Indiana
August 24, 1874 — December 21, 1942

It is difficult to realize when one sees whole buildings in the large universities of our state devoted entirely to chemistry that the history of chemistry as a major subject in Indiana is contemporaneous with the history of our Academy. Moreover some of the greatest names associated with chemistry in the United States were members of our Academy: Harvey W. Wiley, J. U. Nef, T. C. Van Nuys, William A. Noyes, Robert Warder, Alexander Smith, W. E. Stone. Three of these were the first full-time professors of chemistry at Purdue, Indiana University and Rose Polytechnic. Philip S. Baker was the first full-time professor of chemistry at DePauw University, and his successor was William Martin Blanchard, who came to DePauw in 1901 and devoted the next forty years to teaching and research in chemistry.

Dr. Blanchard received his early education in North Carolina and then entered Randolph Macon College from which he graduated in 1894. He spent the next three years in teaching in the Academy and College at Randolph Macon, and then entered Johns Hopkins University where he received the A.M. and Ph.D. degrees, the latter in 1900. He worked under Remsen, whose greatness and personality was a constant source of inspiration to Dr. Blanchard. Following the completion of his doctorate he immediately accepted a position at the Rose Polytechnic Institute, and a year later came to DePauw as successor to Philip S. Baker.

During the next forty years William M. Blanchard became a powerful force for good in state and civic affairs. He served on the DePauw Athletic Committee for thirty-five years and was secretary of the Indiana College Conference for many years. From 1913 to 1927 he was secretary of the DePauw Faculty and became Dean of the College of Liberal Arts in 1927, which position he held until his retirement in 1941. Possessing an unusual and forceful personality he gathered about him many of the keenest minded students in the college and inspired them to such an extent that a survey made several years ago covering several hundreds of his former chemistry major students showed that ninety per cent of them were still active in the field of chemistry and among them were several outstanding American chemists.

He was the author of a college textbook, "Introduction to General Chemistry," and he published a number of research and expository papers which appeared in the various chemical journals and the *Proceedings of the Academy*. He was a Fellow of the American Association for the Advancement of Science and the American Geographic Society, and he held memberships in the American Chemical Society and the National Economic League. He was also a member of Phi Beta Kappa and Sigma Xi. Simpson College conferred an honorary Sc.D. degree on him in 1937. Dr. Blanchard was active in civic affairs and was one of the charter members and a past president of the Greencastle Rotary Club.

For thirty years Dr. Blanchard was one of the most active and influential members of the Academy of Science. He frequently appeared on its programs and influenced many of his undergraduate students to present papers. He served as Treasurer of the Academy for eleven years and was its President in 1926. At its Spring Meeting in 1941 the Academy elected him to Honorary Fellowship.

Dr. Blanchard was a firm believer in sound educational methods and he constantly insisted on high standards and scholastic integrity. He was a scientist in the truest sense and he made a great contribution to the state and nation through his profound influence on hundreds of students who are pursuing successful scientific careers.

FREDERICK JOHN BREEZE

Welshpool, Wales	Lafayette, Indiana
August 10, 1873	October 24, 1943

Frederick John Breeze, for forty-five years a most faithful and active member of the Academy, was born in Welshpool, Wales, and came to America in 1880 with his parents, who settled first in Flora, Indiana, and then a little later at Delphi. His early education was received in Delphi and he graduated from that high school in 1892. He began his teaching work in 1892 in Indiana and later attended Indiana State Normal School, from which he graduated in 1899. The next two years were spent as a science teacher in the Phoenix, Arizona, high school, after which he returned to Delphi and taught science in that high school until 1905. During the next four years he was superintendent of the Remington, Indiana, schools. He then entered Purdue University as a graduate student and instructor in forestry. He received the B.S. degree from Purdue in 1910 and the M.S. degree in 1912. He served as a spring assistant in geography at the Indiana State Normal School in 1908.

Following his graduation from Purdue he was Science Editor for the American Book Company until 1916. He then entered Indiana University for some graduate study and a little later became acting assistant professor of geography at the Indiana State Teachers College. In 1918 he was elected Professor of Geography and Geology at Ball State Teachers College and was made Dean of Science in 1922. In 1930 he went to Fort Wayne as an extension lecturer for Indiana University and instructor of geography in North Side High School, where he remained until his retirement in 1941. He then returned to Delphi and remained there until he was stricken with a heart attack and was taken to a Lafayette hospital where he passed away.

Professor Breeze was a strong advocate of conservation and was ever on the alert to protect bird life and the rarer plants. Previous to 1930 he had set aside twenty-four acres of land along the Tippecanoe River near Delphi as a plant and bird sanctuary, which he named Powys Gardens after the Welsh name of his birthplace and early boyhood home. He was active in the work of the Indiana Audubon Society and had served at its president.

On his return to Delphi he became active in the civic life of that city. He was a member of the Board of Stewards of the Methodist Church and of the Rotary Club. For many years he had been active in St. David's Society, an organization for natives of Wales.

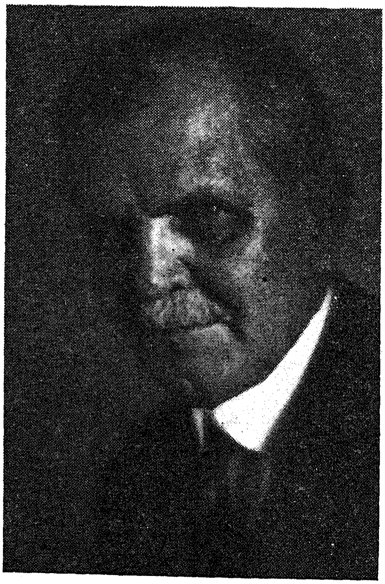
Professor Breeze was a member of the American Association for the Advancement of Science, Sigma Xi and Phi Delta Kappa. He regularly attended the meetings of the Academy, occasionally presented papers, and was sponsor for many of the present members of the Academy. He served on the Archaeological Survey Committee for several years and he was active in the Junior Academy, being a member of its Council from 1935 to 1940. The Academy elected him a Fellow in 1910.

Fred J. Breeze was a fine and useful citizen of Indiana, an earnest student of science, and an excellent educator whose influence will continue in the lives of those whom he taught and with whom he worked.

STANLEY COULTER

Ningpo, China	Lafayette, Indiana
June 2, 1853	June 26, 1943

During the past fifty years the influence of Stanley Coulter has been felt in the State of Indiana in three ways, first, as "the Grand Old Man of Purdue," second, as a powerful advocate and leader of the state



conservation program, and third, as an inspiration to the scientists of the state, both young and old, through his leadership in the Academy of Science. Probably no other scientist in the state was more widely known

nor more universally loved and respected, and his death brought to a close a long life of unselfish service.

Stanley Coulter was born in China of missionary parents and shortly after his birth he and his older brother, John M. Coulter, were brought to this country by his mother on account of his father's death. His maternal grandfather was John Finley Crowe, founder of Hanover College, and the Coulter boys grew up around Hanover and received their public school and college education there. Following his graduation from Hanover College at the age of eighteen, he taught school for a few years, studied law and practiced it at Logansport from 1880 to 1885, after which he taught in Coates College in Terre Haute. He received the A.M. degree from Hanover in 1877 and the Ph.D. in 1889. In 1887 he was invited to come to Purdue as Professor of Zoology, and from that time on until his retirement in 1926 at the age of seventy-three, his life was devoted to the welfare and betterment of Purdue University and the State of Indiana. Shortly after going to Purdue he became Professor of Biology and Director of the Biological Laboratories. In 1907 he became the first Dean of Science at Purdue, and in 1919 Dean of Men. Following the tragic death of President W. E. Stone in 1921 he was Chairman of the Faculty until the arrival of President Elliott in 1922. Upon his retirement in 1926 as Emeritus Dean of Men and Emeritus Dean of the School of Science, he became associated with the Eli Lilly & Company as editorial consultant where he remained until impaired health forced his retirement.

Dr. Coulter possessed that rare ability to get people to cooperate. He loved and understood youth and sympathized with their problems. Cultured, wise and witty, and possessed of an unusual memory, he secured and held the confidence, friendship and admiration of young and old who frequently sought his advice and counsel. For many years he taught a student Bible class in the Lafayette Presbyterian Church in which the attendance was so large it was necessary to hold the class in the main auditorium.

Dr. Coulter was one of the Founders of the Indiana Academy of Science and he was active in its work for fifty-five years. The Academy early worked for the conservation of the State's natural resources and for the preservation of wild animal and plant life. One of the first of his many contributions to conservation was a pamphlet "The Forest Trees of Indiana," in 1892, followed by "The Flora of Indiana," in 1899. Through the efforts of Amos W. Butler, Carl H. Eigenmann, Stanley Coulter, and others, conservation work was begun. Dr. Coulter was appointed to the State Board of Forestry in 1902. When the State Conservation Commission was created in 1916 he was made a member and was chairman from 1926 to 1933. He served the state conservation program for thirty-one years. He was the author of eleven pamphlets on nature study written in the furtherance of this work.

He was interested in many welfare enterprises. For many years he was active in the programs for the prevention of tuberculosis and was one time president of Indiana Society for the Prevention of Tuberculosis, and for a number of years after his retirement from Purdue he was

chairman of the State Christmas Seal Sale. He was a member and one time chairman of the Indiana World Peace Committee. Long a member of the Indiana Audubon Society, he was its president for four years.

Dr. Coulter's principal scientific interest was in botany and he wrote forty-five pamphlets on science studies and reports. His most important work was "A Catalogue of the Flowering Plants and of the Ferns and Their Allies Indigenous to Indiana." As Editorial Consultant of Eli Lilly & Company he revised, enlarged and published a work, "A Pharmacology of Remedies in Common Use." He was also the author of about seventy other articles, book reviews and biographical studies.

Many honors came to Dr. Coulter. Purdue University, Hanover and Wabash Colleges conferred honorary degrees on him. The building devoted to the biological sciences at Purdue was named Stanley Coulter Hall. He was cited in 1939 by the Indianapolis Chamber of Commerce for his outstanding achievements. The Academy of Science devoted its general meeting at Purdue in 1938 to honoring him and his long time colleague, Joseph Charles Arthur, and he was elected to Honorary Fellowship in the Academy some years previously. He was president of the Academy in 1896.

Dr. Coulter was a member of the American Association for the Advancement of Science, the Western Society of Naturalists, the Botanical Society of America, the American Genetic Society and the Central States Forest Research Council.

With the death of Stanley Coulter the Academy has lost its last active charter member who remained in the State. He knew all the great scientists of the past who have been associated with the Academy, and when the history of science in Indiana is written the name of Stanley Coulter will take its place with the names of the other giants of those days.

MARTIN LUTHER FISHER

Murray, Indiana
October 24, 1871

Lafayette, Indiana
December 1, 1942

When Dr. Stanley Coulter retired as Dean of Men at Purdue in 1926, his successor was Martin Luther Fisher. To follow Dean Coulter, whose hold on the student body and alumni was tremendous, was no easy task. However, Dean Fisher, whose connection with Purdue began in 1894 as a student and who in 1926 was Assistant Dean of the School of Agriculture, possessed those traits of calmness, fairness, sympathy and wisdom that soon secured for him the confidence and respect of the student body and endeared him to both students and alumni.

Martin L. Fisher was born on a farm in Wells County Indiana. After completing his public school education he taught in the rural schools of his county. He entered Purdue University in 1894 and remained two years, after which he returned to teaching in the rural schools and then the Bluffton public schools. Re-entering Purdue in 1901 he graduated in 1903 from the School of Agriculture, and immediately joined the

teaching and research staff of the School of Agriculture. He was made Professor of Agronomy in 1910 and Assistant Chief of the Soils and Crops Department of the Agricultural Experiment Station, and in 1921 he became Assistant Dean of the School of Agriculture. During this period he received the M.S. degree from the University of Wisconsin in 1911.

Dean Fisher was an excellent teacher as well as a most successful executive. His teaching was direct and forceful, and he left a lasting impression on his students through his integrity and sincerity. For many years in the School of Agriculture he had charge of the class schedules and attended to the curriculum revisions. As Dean of Men, students soon realized that they were dealing with a sincere, honest and just man who was their friend even under most trying circumstances. Like his colleague and predecessor, Dean Coulter, he taught a student Bible class in the West Lafayette Methodist Church for over twenty years.

While actively associated with the School of Agriculture Dean Fisher wrote a number of Agricultural School bulletins and pamphlets and numerous articles for farm papers. He was also a joint author of a text, "Agriculture for the Common School," widely used in Indiana. He pioneered in the establishment of vocational agriculture in the State and frequently spoke at farmers' institutes and short courses. As a student of the soil he naturally was much interested in botany and bird study. He enjoyed botany and bird hikes and had considerable skill in plant identification. He conducted bird study tours during the annual Purdue 4-H Club Roundup, and also at other times with university student groups. Long a member of the Indiana Audubon Society, he was its president in 1919.

Dean Fisher was a member of the American Society of Agronomy, and the Association for the Advancement of Agriculture. He had been a member of the Indiana Academy for more than a third of a century and was made a Fellow in 1919. He frequently made reports on plant or bird study, and appeared for the last time on an Academy program in 1940 when he gave a paper before the Psychology Division on "A Study of the Scholastic Trends of Fraternity Men." Dean Fisher was vice-president of the Academy in 1934 at the semi-centennial meeting. The Academy has cause to be proud that men like Martin L. Fisher and Stanley Coulter, whose influence for good in the State has been so great, also valued their Academy association so highly as to maintain an active interest in its work to the end.

ROBERT HESSLER

Cincinnati, Ohio	Indianapolis, Indiana
June 7, 1861	December 17, 1942

With the death of Dr. Robert Hessler on December 17, 1942, in Indianapolis, the Academy lost another of its few remaining charter members. Born in Cincinnati, he went at an early age with his parents to Batesville, Indiana, where he completed his public school education. In 1880 he became a resident of Connersville. He was a nature lover,

deeply interested in botany and geology, and spent most of his spare time roaming the fields and woods collecting plants, fossils and geological specimens. When the Brookville Society of Natural History was formed in 1881 by the Reverend David R. Moore, Amos Butler and Edgar R. Quick, young Hessler was asked to join, and when the Brookville Society sponsored the organization of the Academy in 1885, he became a charter member of the new organization.

His membership in the new organization and his contacts with David Starr Jordan, John C. Branner and others evidently influenced him into entering Indiana University in 1886 from which he graduated in 1890. He then entered the Medical College of Indiana, graduated in 1892, served an internship in the Indianapolis City Hospital, and practiced medicine in Indianapolis until he was appointed in 1894 House Physician for Men at the Northern Indiana Hospital for the Insane at Logansport. In 1897 he was transferred as pathologist to the Central Hospital in Indianapolis. The following year he went to Europe for study and travel. In 1900 he located in Logansport, where he practiced medicine for the next twenty-one years, after which he returned to Indianapolis, where he practiced some but devoted most of his time to research work.

Dr. Hessler's association with the State Hospitals deeply affected his future study. He became intensely interested in the influence of heredity and environment, particularly as that environment had to do with health conditions. The study of ill health and its causes became a major interest with him, and he constanly advocated and worked for sanitary improvements and other measures that would prevent or lessen disease. To him most cities were the "graveyard of man," on account of their dust, smoke,

filthy streets, crowded conditions, and the artificial climate of the homes and business houses in which so much of the city dweller's life is spent. He wrote numerous papers on various phases of this subject which were published in the journals of the American Medical Society and the Indiana Medical Society and the *Proceedings of the Indiana Academy of Science.*

He also wrote a number of papers on bacteriological and pathological subjects. He did some good work in botany, but he did not publish a great deal. He was the author of one book, "Dusty Air and Ill Health," which appeared in 1912.

Dr. Hessler was elected a Fellow of the Academy in 1899 and was chosen president in 1906. His presidential address was on "The Evolution of Medicine in Indiana." He maintained a deep interest in the Academy throughout his entire life and appeared frequently on its programs. He was a man of deep convictions and had the courage to stand for what he believed was good. A number of the proposals which he made years ago for health improvement, though unpopular at the time he made them, are now recognized as sound sanitary measures. There is a certain satisfaction in knowing that Dr. Hessler was privileged to live long enough to see the enlightenment in public opinion that has led to some fulfillment of his hopes.

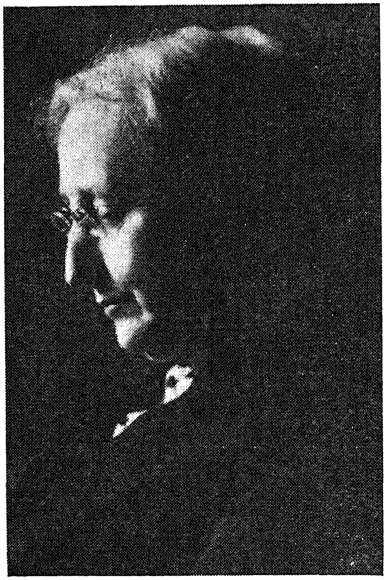
LILLIEN JANE MARTIN

Olean, New York	San Francisco, California
July 7, 1851	March 26, 1943

Lillien Jane Martin was the only woman among the Founders of the Indiana Academy of Science. This unique distinction was more or less characteristic of Miss Martin's whole life, for she was a pioneer in much of what she did and accomplished. And she remained professionally active almost up to the day of her death and most of her humanitarian work was done after she had passed the age usually assumed for retirement.

She was born in Olean, New York, on July 7, 1851, and received her early education in that state. She graduated in 1880 from Vassar College and immediately came to Indianapolis as a science teacher in the Indianapolis high school, now known as Shortridge High School. She taught botany, physics and chemistry. In 1889 she resigned to accept a position as vice-principal and head of the department of science of the Girls' High School in San Francisco. She remained there until 1894 when, at the age of forty-three, she decided to give up high school teaching and begin the study in the new science of psychology. Accordingly she went to the University of Göttingen, in Germany, where she worked under the psychologist, G. E. Mueller, for the next four years. Returning to America in 1899 she was called to Stanford University as Assistant Professor of Psychology where she remained until she was retired in 1916, at the age of sixty-five, as Emeritus Professor of Psychology. During her time at Stanford she returned to Germany for further brief

periods of study at Würtzburg in 1907, Bonn, 1908 and 1912, and Munich, 1914. The University of Bonn conferred the honorary Ph.D. on her in 1913. She worked in the general fields of psychology and also in the special fields of aesthetics, the subconscious, and the psychology of humor. She was the author of eleven books, both in English and German, and of numerous articles in psychological and other journals.



Immediately following her retirement from Stanford she set up clinical offices in San Francisco. She became active in the California Society for Hygiene, and in 1920 she established a clinic for normal children of pre-school age. Her clinical experience in child guidance was broad. About 1930 she set up her Old Age Center for the rehabilitation of aged people, and during the next twelve years she handled over one thousand cases. She was a pioneer in clinical psychology.

Miss Martin was a remarkable woman of indomnitable will, keen mind and an iron constitution. She learned to handle a typewriter at the age of sixty-five, and to drive an automobile at the age of seventy-eight. She drove across the continent twice in her car and also made an extensive trip into Mexico. She made a tour around the world when she was seventy-four, and traveled alone to Russia when she was seventy-six. At the age of eighty-eight she spent a year in travel in South America, crossed the Andes by airplane, and took a boat trip up the Amazon. At the age of seventy-nine she collaborated with her assistant in the authorship of a book "Salvaging Old Age," and of a second book "Sweeping the Cobwebs," when she was eighty-two.

She was a most cultured and charming woman, deeply interested in the welfare of the human race. She held membership in a number of

scientific societies and was at one time vice-president of the Psychology Section of the American Association for the Advancement of Science. She was also active in the California League of Women Voters, and other women's organizations.

Dr. Martin had not been active in the Academy for many years, but she numbered among her friends many of the older members of the Academy. She was unable to be present at the Semi-Centennial Meeting of the Academy in 1934 but she sent her greetings. The Academy is indeed fortunate to have had this remarkable pioneering scientist as one of its Founders.

LOUIS AGASSIZ TEST

Dundee, Illinois
June 18, 1874

Ann Arbor, Michigan
April 23, 1943

Louis Agassiz Test, Emeritus Professor of Chemistry at Purdue, was the son of Dr. Erastus Test, Professor of Mathematics at Purdue from 1889 to 1910, and a great deal of his life was spent at that University. He and his twin brother, Charles D. Test, were born at Dundee, Illinois, on June 18, 1874. Both boys entered Purdue and graduated in 1894. Dr. Louis A. Test graduated as a mechanical engineer, but later took up chemistry which became his life's work. In order to prepare himself thoroughly for this work he entered the University of Chicago where he received the Ph.D. degree in 1907. He immediately accepted a position at Occidental College, in California, as Professor of Chemistry, and two years later began teaching in the Missouri School of Mines. In 1913 he accepted a position in the chemistry department of Iowa State College, remaining five years, and then coming to Purdue as Professor of General Chemistry. He retired in 1940 as Emeritus Professor of Chemistry and went to Lindsay, California, where some years before he had purchased a fruit ranch.

Dr. Test was primarily an educator and he was deeply interested in the problems of youth, particularly college freshmen. For many years he had charge of the freshman chemistry courses and laboratory at Purdue. In 1932 he was chairman of a symposium on The Teaching of Freshman College Chemistry, held at Notre Dame as part of the Academy program. A deeply sincere man of Quaker ancestry, he was superintendent of the Presbyterian Church School for a number of years.

While he wrote a number of chemical research papers that appeared in the various chemical journals and the *Proceedings of the Academy of Science*, he was best known in the Academy for his bird studies. He established the first bird banding station in West Lafayette in 1924 and for the next fifteen years reported regularly on his results. He early made a pal of his son, Frederick H. Test, now on the staff at the University of Michigan, and father and son tramped the woods and explored the State Parks together, studying birds, plants and rocks. They made and published many joint reports on the progress of their studies. Dr. Test was a past president of the Indiana Audubon Society.

Dr. Test was a member of the American Association for the Advancement of Science and the American Chemical Society. He was a Fellow of the Indiana Academy of Science and served as its secretary for two years and as its vice-president in 1939, when he actively assumed charge of the Winter Meeting due to the absence of the elected president.

He was stricken with a heart attack in Chicago while on his way to Ann Arbor to visit his son, and after spending several weeks in the hospital had apparently recovered sufficiently to go on to Ann Arbor, but he succumbed the day following his arrival in Ann Arbor.

BROTHER RAPHAEL (VALENTINE MARCZYNSKI)

Chicago, Illinois
February 2, 1907

South Bend, Indiana
February 11, 1943

It is with deep regret that one records the passing of a young man whose scientific future seemed assured. Brother Raphael, one of the most brilliant younger members of the Congregation at Notre Dame, died at the age of thirty-six following a baffling illness that began a few days after he had appeared for the first time on an Academy program at the meeting held in Notre Dame in November, 1942.

Brother Raphael entered the Congregation in 1923, while a youth, and completed his preliminary education in the Congregation's high school at South Bend, and then entered Notre Dame University. He had the unique distinction of receiving four degrees from the University, B.S., 1930; M.A., 1936; M.S., 1939, and Ph.D. in December, 1942. He had taught in several of the Congregation's high schools in Chicago before returning to Notre Dame to work for his doctorate. For the last four years of his life he was connected with the Department of Biology at Notre Dame and was appointed a regular member of the Faculty in September, 1942.

Brother Raphael joined the Academy in 1942 and was known to only a few members of the Academy. However, his able presentation of some research in botany at the meeting of that section in 1942 made a very favorable impression and one can but feel that the Academy and Notre Dame University have suffered a distinct loss.

MOTHER MARY VERDA (MARGARET DORSCH)

Baltimore, Maryland
September 20, 1887

Ann Arbor, Michigan
September 20, 1942

Mother Mary Verda, Mother Provincial of the Midwest Province of the Sisters of the Holy Cross, passed away in the University Hospital at Ann Arbor, on her fifty-fifth birthday, bringing to a close a life of good works and beneficient service. She was born Margaret Dorsch in Baltimore, Maryland, where she received her early education, and graduated in 1907 from Saint Catherine's Normal Institute. She entered the novitiate at Saint Mary's at Notre Dame that summer, and received the Holy Habit and became Sister Mary Verda in December, 1907. Follow-

ing a year's novitiate she was sent on a mission to Saint Mary's Academy, Salt Lake City, and the following year to Saint Cecelia's Academy, Washington, D. C., where she remained until 1921. During her years in the East she studied at Catholic University and Johns Hopkins University, philosophy and education being her major fields of interest.

She returned to Saint Mary's, Notre Dame, in 1921 to become Head of the Department of Philosophy. During the next eighteen years practically every philosophy class was under her supervision and virtually every student and Sister of the college came under her influence during that period. While doing this work she continued her studies and received the Ph.D. degree in 1925 from the University of Notre Dame. Following the completion of her study for the doctorate she focused her attention on the philosophy of Saint Thomas Aquinas. She spent the summer of 1935 in Europe, in Italy, France and England, doing some study at Cambridge, and before her death had become recognized as an authority on American new realism.

In 1939 she was chosen Mother Provincial of the Midwest Province of the Sisters of the Holy Cross, and she left the class room to take up this work of community service which she continued until her untimely death. Sister Mary Verda was an inspiring teacher and much of her work was directed toward character building.

Mother Mary Verda held membership in the American Philosophical Association, American Psychological Association, Mediaeval Academy of America, Pi Gamma Mu, and the American Catholic Philosophical Association, and she served as an executive councilor in the latter organization from 1925 to 1929. She became a member of the Indiana Academy of Science in 1935 and presented a paper before the Psychology Division in which she stated that she hoped that meetings of the natural scientists and psychologists, like those of the Academy, would help to bring about a reapproachment between philosophy and science. It is to be regretted that the opportunity to become more active in the Academy was denied Mother Mary Verda, for the Academy has need for the active participation of more scholarly women who are sincerely interested in the development and improvement of science.

PRESIDENTIAL ADDRESS

The Rates of Evolutionary Processes

THEODOR JUST, University of Notre Dame

Introduction. It has often been claimed that evolution progresses by two essentially different types of changes, namely macro- and micro-evolutionary changes; or expressed differently, that major systematic categories like orders and phyla "pass through an orderly series of changes" or "programme evolution," while groups of species "evolve progressively along a certain line of change or 'trend'" (Dobzhansky 1941, Waddington 1939). Paleontology is supposedly responsible for the examples of programme evolution, while genetics offers the available data concerning trend evolution. Needless to say, the geneticist confines his attention to the micro-evolutionary changes which he can attack experimentally. But is the practice of contrasting these types of evolutionary changes necessary or justifiable on the basis of available information?

Paleontologists and geophysicists have taught us to think in immense spans of time, long enough to embrace the vast panorama of organic evolution, and excusably may find it difficult to accept the findings of modern genetics—so far our only experimental approach—based on such incomparably shorter periods of time and limited numbers of generations. Despite their great youth, genetics and the accompanying study of speciation furnish an overwhelming body of pertinent information, which is now fortunately replacing most of the unproductive controversy concerning evolution so widespread only yesterday. It is no longer impossible to visualize evolution in terms of processes known today and within the time limits available for it. This does not imply that all problems have suddenly been answered but certainly that fewer remain to be solved.

The species concept, past and present. Taxonomists are often accused of defining species in a subjective manner and without recourse to a generally applicable species concept. Disregarding the difficulties resulting from abuses of the older species concept, biologists have now come to recognize the fact that species of identical hierarchical value do not exist in the numerous groups of the animal and plant kingdoms. Naturally this realization leads to the practice of distinguishing different kinds of species, not to confuse the taxonomist but rather to interpret correctly the great diversity of forms encountered in nature. If this is so, more than one mode of the "origin of species" must be sought, tested experimentally and recognized as effective evolutionary mechanisms in speciation. These modes are likely to differ in many respects and are bound to progress at different rates. As these processes are analyzed and established on general grounds, the picture of evolution is likely to change. Evolution will not be simplified or reduced to a simple formula.

Rather the evolutionary processes will be removed from speculation and placed in proper perspective.

It can easily be shown that the term species is applied to groups of very different genetical status. Several ways of distinguishing kinds of species can be followed. Thus Darlington (fide Waddington, 1939) lists six types of species variously affected by evolutionary mechanisms and differing in degree of hybridity. Elsewhere (Darlington, 1940) he speaks of genetic systems which make up the various kinds of species. "There are many kinds of species and many kinds of discontinuities between species; there are also many kinds of hybridity and isolation. These differences depend on the different kinds of genetic systems at work in plants and animals; but they cannot be arranged in a simple table because they occur at different levels of integration."

Significantly Sewall Wright (1940) points out that "it has become necessary to shift the emphasis in the definition of species from the essentially physiological concept, kind, to the ecological one, the interbreeding population."

Dobzhansky's (1941) definition, admittedly applicable only to sexual and cross-fertilizing forms, was proposed to "define species as that stage of evolutionary process, 'at which the once actually or potentially interbreeding array of forms becomes segregated in two or more separate arrays which are physiologically incapable of interbreeding.'" The emphasis is here clearly placed on the dynamic nature of the species concept, or in his words "the species is a stage in a process, not a static unit." This definition cannot serve as a yardstick for the practical taxonomist. Mayr (1942) considers it "an excellent description of the process of speciation, but not a species definition. A species is not a stage of a process, but the result of a process."

Mayr's (1942) short definition reads as follows: "species are groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups." Although it may cover most cases, Mayr believes that it is "doubtful whether this species definition applies equally well to plants" in view of the many differences between plants and animals listed by him. Turrill (1942) is of the same opinion, because many good species of plants are not as definitely separated genetically and cytogenetically as required by these definitions.

In his analysis of the species concept Mayr (l.c.) distinguishes *sympatric* species with overlapping or coinciding areas from *allopatric* species with geographically separate areas. The gaps between sympatric species are absolute, whereas those of allopatric species are frequently gradual and relative. These two kinds of species are contemporary or *synchronic*. Their recognition may be difficult at times but never as complicated as that of *allochronic* species belonging to different time levels.

The latest botanical counterpart to the practice of distinguishing these types of species based essentially on ecological criteria is *biosystematy*, which is characterized by Camp and Gilly (1943) as an expanded phase of classical taxonomy employing new techniques and a new outlook, primarily genetical criteria. According to these authors: "biosystematy

seeks (1) to delimit the natural biotic units and (2) to apply to these units a system of nomenclature adequate to the task of conveying precise information regarding their defined limits, relationships, variability, and dynamic structure." Biosystematy requires genetical analyses in addition to morphological and biogeographical studies. This practice will lead to different results from those based on conventional taxonomic procedure, or, as Turrill (1942) puts it: "the genetical species or other group does not necessarily coincide with the taxonomic." Hogben (1940) states it in another way: "the word 'species' has no single meaning. Hence there is no one problem of the origin of species. There are many problems of the origins of species."

Using a genetical approach, Camp and Gilly employ two primary criteria in their work: "(1) the appearance of species-populations in the field and (2) the genetic systems operative within these populations."

On this basis they recognize two major kinds of species: a) species in which apomixis is not present, and b) species in which apomixis is present. The species without apomixis are of ten kinds: homogeneon, phenon, parageneon, dysploidion, euploidion, alloploidion, micton, rheogameon, cleistogameon, and heterogameon. The species exhibiting apomixis, on the other hand, belong to one of two kinds, apogameon and agameon.

The subspecific categories recognized in biosystematy are: phenogen, subspecies, forma, and stropha.

Throughout their study a sincere effort is made to recognize the attainments of genetics and the accomplishments of taxonomy in order to find a common basis for future work and mutual understanding.

Despite certain differences of definition and delimitation, all of these concepts agree in their dynamic approach, in their attack on the problem via speciation or the various modes of speciation. As ecology profited once by the introduction of the dynamic viewpoint, taxonomy may benefit equally from this almost revolutionary change in its outlook, orientation, and methodology.

Modes of speciation. It is impossible to attempt here a complete enumeration of all known and probable processes of speciation. This has never been done and seems, for the time being, somewhat premature, because experimental work is still too young and in a state of flux. Dobzhansky (1941) lists the following patterns of evolution: "gene mutation, chromosome changes, restriction of the population size, natural selection, and development of the isolating mechanisms are the known common denominators of many, if not all, evolutionary histories. Different phylogenetic lines vary, however, in that one or the other of these evolutionary agents may become limiting at different stages of the process. Polyploidy, self-fertilization, apogamy, and asexual reproduction create very special conditions, . . ." sometimes very sudden or "cataclysmic" changes.

"From the viewpoint of a zoologist" Mayr (1942) lists the following modes of speciation:

A) geographic, with its five stages;
B) semigeographic (origin of species gaps in zones of intergradation); taneous or gradual.
C) nongeographic (sympatric speciation), which may be either instantaneous or gradual.

Geographic speciation is by far the most common, whereas little evidence supports the nongeographic modes.

Geographic speciation includes two processes: "the development of diversity and the establishment of discontinuities between the diverging forms." It is not an abrupt but gradual and continuous process, because all imaginable levels of speciation are found in nature. A vast amount of pertinent information is supplied by the author to illustrate this most effective mode of speciation.

Mayr also emphasizes certain differences between plants and animals, which are reflected in their respective modes of speciation. Actually so far no similar and equally exhaustive treatise of speciation in plants has come to the speaker's attention, irrespective of many excellent monographic studies.

Finally, Rensch (1939) discusses first speciation and then the origin of higher categories. He explains even transformations of the body as a whole by undirected mutation and selection, and claims that the evolutionary phenomena recognized in paleontology can be understood without the assumption of any inner unfolding impulse. Although irreversibility is known, it has theoretically been disproved by reverse mutations. The actual irreversibility is said to be due to the complex conditions of life, which render a return to identical situations for mutation and selection practically impossible. Orthogenetic series are explained largely through continued selection of larger variants and resulting changes in proportion due to heterogonic growth of single organs, or orthoselection. "Explosive development of new forms and later diminution of species formation should not be ascribed to varying rates of mutation, since mutation is steady, but to increasing occupation of the available biotopes with competing forms. Ageing and extinction of evolutionary series is to be explained by an increased restriction to narrow habitats and specialization due to selection, by selectively caused increase in size, and by the consequent development of monstrous organs." "Even the perfection and the higher development of organisms is due to no unknown law of development, but merely to the fulfillment of the available possibilities, including increase in complication and physiological amelioration and simplification."

Estimated and known rates of evolutionary processes. Now that the principal modes of the origin of higher and lower systematic categories are established, there remains the question of determining what is known regarding the rates of the processes involved introducing them. As will be clear from the following discussion, our knowledge in this respect is quite scanty and unequal.

Ritchie (1941) emphasizes strongly the slowness of evolution. To illustrate the point, he gives a new estimate of the evolution of the modern

horse (*Equus*) from its precursors during Eocene times. He states that "the whole gamut of changes which modified the four toed forelimb of *Eohippus* into the single toe of *Equus*, from lower Eocene to Upper Pliocene, occupied about 57 million years. It took some 17 million years to reduce the four effective digits of *Eohippus* (Lower Eocene) to three in *Mesohippus* (Lower Oligocene), and 22 million more to raise the two lateral digits clear of the ground (in *Merychippus*, Middle Miocene). The penultimate stage of reducing the ineffective side digits to vestigial splints (in *Plesippus*, Upper Pliocene) occupied some 16 million years, and the gradual reduction of these vestiges to the condition seen in the modern horse (*Equus*, Upper Pliocene) probably took about another two million more."

These estimates concerning the evolution of various genera leading up to the modern horse should certainly cover speciation within these groups. Other examples of slow evolution could probably be provided but perhaps with less definite estimates of the periods of time involved.

Evolution obviously progresses more rapidly in other cases, especially in organisms less widely distributed. After reviewing the geological and entomological evidence Zimmerman (1942) for instance concluded: "There appear to be no indigenous elements in the eastern oceanic insect faunas that demand as great or greater age for their developments as for such creatures as the horse and elephant, or, for that matter, man, who, it is believed, developed from Miocene primates derived from the Eocene lemuroides of North America." Ernst Mayr (in litt.) concurs with this thesis.

The post-glacial development of many animals and plants has been realized for a long time despite the varying time limits set for these processes by different authors. Ritchie sets a maximum of 20,000 years for the evolution of seven different and distinctive species of mammals endemic in the outer islands of Scotland.

An excellent botanical example is given by Marie-Victorin (1938). The freshwater tidal shore of the St. Lawrence River is characterized by the presence of many estuarine endemics of post-glacial origin. This author believes that this area represents the "richest Oenothera territory in Quebec and possibly in the whole of northeastern America." The factors claimed to be responsible for this accelerated development of endemic species[1] in post-pleistocene times are the double daily cycle of emersion and immersion, diminished competition, the operation of efficient devices for seed dispersal, etc.

Man has permanently influenced and determined the course of evolution followed by many cultivated plants and domesticated animals. Three examples should illustrate this sufficiently. On the basis of archaeological and botanical evidence Mangelsdorf and Reeves (1939) concluded that teosinte (*Euchlaena mexicana*) originated in Guatemala between 600 A.D. and 900 A.D. by the hybridization of Zea and Tripsacum.

The other two cases involved even shorter spans of time. Marie-Victorin (1938) has shown that "under favorable circumstances, a period of two or three hundred years is sufficient to produce, in some genera

[1] Regarded as geographical races by Cleland (1944).

at least, by mutation or otherwise, a marvelous outburst of species, or at any rate, of recognizable forms." This conclusion is based on extensive studies of Crataegus and Oenothera populations[2] in the immediate neighborhood of the older Canadian cities like Quebec, Montreal, Toronto, and old Hudson Bay forts. Apparently deforestation and settlement during the short colonial period resulted in considerable migration and multiplication of recognizable forms.

The last case of this sort is the domestication of the European rabbit, *Oryctolagus cuniculus,* which among mammals is second only to the dog in variability. The facts (Nachtsheim 1936) are as follows: the development of at least fifty well marked breeds began with the sixteenth century; mutants can be traced historically and concern characters other than coat color, etc.; five mutants of coat color were known by the end of the sixteenth century, seven around 1700, three more appeared by 1850, three additional ones by 1900, and six between 1900 and 1935.

A normal minimum for distinct subspeciation of 5,000 years was determined by Moreau (fide Huxley 1942) on the ground that the Nile Delta has in part become land within the last 5,000 years and lacks endemic passerine subspecies, and has only a limited number of others. Additional cases of this sort are given by Huxley (1942) and Mayr (1942).

Only a few years seem to have been required for the separation of two distinct local populations of a moth, *Oporabia autumnata,* known to inhabit two ecologically distinct woodlands. These populations are said to differ in size, color, and certain physiological characters (fide Huxley 1942).

After determining by extensive collections the number of species of the genus Cynips known to occur in Mexico and Southwest, Kinsey (1936) estimated the rather low number of mutations needed to account for their existence. The group originated in the Miocene, some ten or twenty million years ago. "One mutation in 20,000 years would, if properly timed and placed, account for the 100 species of *Cynips* known in this area. The laboratory rate of plus mutations even in *Drosophila* would, if extended over the thousands of square miles and tens of millions of years involved, be ample to account for the condition we find in nature."

On paleobotanical grounds Zimmermann (1930) attempted similar estimates. A low estimate places the boundary between the Miocene and Pliocene some two million years ago. The fossil flora of Oeningen is well known and mostly made up of woody species fairly close to living species. If one assumes that it requires on an average twenty years for these woody species to produce flowers and set fruit, one could translate this time into 100,000 generations. If only one viable mutation occurred per every 1,000 generations, one hundred mutations would appear during the available time. Two plants differing in 100 genes should at least belong to two different species. Surely within the span of 1,000 generations one mutation of selective value could be expected to appear. Speciation ("phylogenetischer Artschritt") has, in other words, two million years

[2] See footnote 1.

at its disposal, an assumption which is easily compatible with present genetical knowledge. By the same token, herbaceous plants require correspondingly less time, e.g., two to three years after the seeds are sown, fruits are likely to be produced. Since the present angiosperm families appeared largely during the Cretaceous, at least thirty million years ago, it is possible to apply 15 times the time limit set for speciation. On that basis these plants should be far enough differentiated barely to be included in the same family. This means, roughly speaking, that thirty million years would permit the development of different families. Later Zimmermann (1938) reduced his estimate for speciation to 500,000 years or the appearance of 1,000 visible mutations, assuming that one large mutation would appear every 500 years or per 100 generations. Intraspecific evolution would, of course, require correspondingly shorter spans of time.

The foregoing discussion is based on estimates derived from various sources and by different ways of calculation. A review of the highly significant mathematical studies concerning this problem by R. A. Fisher (1930), Sewall Wright and others cannot be attempted in this paper.

In recent years the problem has been approached experimentally and summarized by Timoféeff-Ressovsky (1940), who concluded "that the total mutation rates per generation are rather low and in the order of magnitude of 1-10 per cent. Variation in the factors of the normal environment of the organisms have little or no influence upon the mutability. Different single mutation-steps have different rates of change, lying in the order of magnitude of 0.001-0.00001 per cent."[3]

Although considerable information is on hand regarding induced mutations and the frequency of their appearance, less is apparently known concerning spontaneous mutation rates and the causes affecting them (Plough 1941). Nevertheless Plough believes that increases in mutation frequency can speed up "the automatic processes of natural evolution," although they can not change their direction. While studying unstable genes, Demerec (1941) found genes which affect the mutability of other genes and which, in *Drosophila melanogaster*, seem to increase the mutability of the whole gene complex. Neel (1942), who recently found a case of high mutation rate, states that at present at least two factors are known which have a definite effect on mutation rate in Drosophila. Other cases have, however, been reported since. In Neel's opinion, future studies may disclose that much of the mutation found in nature may occur in "such spurts, resulting in the formation of localized populations of relatively high genetic heterogeneity." If this should be so, "a mechanism which may rank in importance with geographical isolation in the process of species differentiation, and one which, in any

[3] According to Timoféeff-Ressovsky (1940) rate of mutation means "the percentage of gametes or haploid genomes containing a mutation. In this case, by 'total mutation rate' is meant the percentage of gametes (of one generation) containing any kind of mutation." Other mutation rates can of course be determined for special types of mutations etc. Elaborate and variously effective methods have been worked out. Recently Stevens (1942) has compared various methods regarding their statistical accuracy.

event, offers a valuable supplement to isolation", would then become known.

Two other cases of genes increasing mutation rates are now reported. Tiniakov (fide Huxley 1942) detected in wild drosophilas "a gene increasing mutation-rate at least 40 times, and possibly to a level higher than that induced by X-rays." According to Mampell (1943) a case of abnormally high mutation rate in *Drosophila pseudoöbscura*, race B, is due to the presence and action of a "mutator gene." The latter increases the normal spontaneous rate about 34 times in heterozygous condition and about 70 times when homozygous. The increase in mutation rate is in this case linear with the dosage of the mutator gene.

Rhoades (1941) has found "a situation in maize where an extremely stable gene is made highly unstable when subjected to a specific genetic environment". Other genes in maize are known to vary greatly in their spontaneous mutation rates. Obviously more information on mutation rates in other plants would be very desirable.

Hybridization apparently increases the mutation rate in some cases. Sturtevant (1939) studied backcrosses from hybrids between the two races (A and B) of *Drosophila pseudoöbscura* and recorded about 9 per cent of lethals and one-half of 1 per cent sex-linked visibles. He also believes that "natural selection must operate to keep the general mutation rate of a species at a minimum." Shapiro (1939) reached essentially the same conclusion.

By comparison Berg (1941-1942) claims that "hybridization disturbs the mechanisms assuring high mutability that have been created during the course of evolution." Furthermore Berg contends that mutation rates are not reduced during evolution and believes that they may even increase under certain conditions. The main factor of increase is "selection for adaptability, which proceeds against a background of struggle among separate groups." Finally Berg showed that mutation rate decreases as isolation increases near the boundary areas of the species distribution. He also reached this important conclusion: "the stability of the variation of the mutation rate under identical conditions, as well as the similarity of the rate under varying conditions, should be taken to mean that mutability is an adaptive character of the species."

The shortest possible time for changes in gene arrangements found to date has recently been reported by Dobzhansky (1943) for certain populations of *Drosophila pseudoöbscura*. In some localities the relative frequencies of the gene arrangements change in these populations from month to month and show thus a cyclic and seasonal cycle reflecting apparently the annual climatic cycle. While populations of a certain locality are apparently alike at any one time, they may readily be permanently different if occurring 10 or 15 miles apart. These changes are ascribed to "natural selection favoring the carriers of different gene arrangements at different seasons of the year". Although different sampling might alter the data obtained, this case illustrates an instance of rapid transformation of populations.

Little, if anything, has so far been said regarding lower organisms and their behavior in this respect. After comparing the rates at which

variants appear in viruses, bacteria, and Drosophila, Gowan (1941) concluded that they are of the same order of magnitude and nature (mutations). (See also Luria and Delbrück (1943) for additional data on mutation rates in bacteria). An exceedingly high mutation rate, 38 to 87 per cent with a rise of temperature from 10° to 35°, was recorded by Sonneborn (1942) for *Paramecium aurelia*, variety 1. This rate seems to compare favorably with Mampell's values.

A very different case is that of an experimentally produced race (chromosome doubling in haploid gametophyte, n = 10) of *Bryum caespiticium* (normally dioicous) studied by Wettstein (1937). This race, *B. caespiticium bivalens*, is an autopolyploid (diploid, n = 20) and a gigas type of high sterility. It undergoes a gradual transformation of its entire genetical constitution which is equally shown in the original plant, its vegetative offspring and the offspring raised from spores. In the course of the experiment one individual of F_1 generation was raised from a spore and showed increased production of sporogones, while it reduced its cell size to that of normal haploid plants within eleven years without change in the chromosome number. This new plant, called *Bryum Corrensii*, is completely fertile and produces normal spores. But more significant than this fact is that Wettstein succeeded in finding a wild type (related species with n = 20 and monoicous gametophyte) which is also polyploid and fertile and which, in all probability, arose in the same manner as *B. Corrensii*. This is at least one case demonstrating the importance of polyploidy in the origin of some new species and the time required for it (see also Dobzhansky 1941, p. 231, and Fagerlind 1941).

Judging by these estimated and known values of mutation rates, we may agree with Huxley who states that "in general it seems that from the standpoint of mathematical theory, existing mutation-rates will in moderately abundant species suffice, with the aid of selection, for the distinctly slow processes of evolutionary change to be observed in fossils".

It must be pointed out in this connection that mutation rates are not the only effective factors determining the speed of evolutionary processes. Highly significant in this respect are also various ecological factors such as population size, dispersal, natural selection and others. The intricate operation and interaction of these have been elaborately described and substantiated by Dobzhansky (1941) and Mayr (1942), whereas some mathematical possibilities have been explored by S. Wright (1940).

Higher Systematic Categories and Mutations. It is by now a time-worn accusation that mutations are too small and injurious to be of sufficient magnitude to account for superspecific evolutionary processes, irrespective of their cumulative values. I mention only two recent examples, namely Willis' evolution by differentiation and Goldschmidt's systemic mutations (1940). What is the evidence which can be brought to bear on this objection?

Hurst (1933) showed clearly that mutations affecting specific, generic, and family characters immediately become varietal and Mendelian

in behavior, or as he puts it, the mutation "loses its high status." He cites the case of the mutant "tricarpel" found by Blakeslee in Datura. This is obviously an exception to the two-celled ovary of the Solanaceae, an important taxonomic character of the family. Zimmermann (1938) described several noteworthy mutations in *Anemone Pulsatilla,* an archichlamydeous (dialypetalous) species. Of these one mutant was definitely gymnospermous and died without setting fruit. Another mutant was characterized by the fusion of the petals and the last showed a modified cotyledon leaving the other one functional. The characters involved are typical of the angiosperms, of the Archichlamydeae or better the Dialypetaleae, and of the Dicotyledoneae. As far as the appearance of beneficial mutations is concerned, the known cases are definitely on the increase in such carefully studied organisms as Drosophila and Ephestia as well as others. Muller (1939) points out that the occurrence of reverse mutations is a further argument for the refutation of this objection.

According to Hurst (1933) varietal, specific, generic, and family characters do not differ in kind but merely in the degree of stability and mutability in nature. On this basis—and there is ample evidence for it—the characters distinguishing the present higher groups appeared during geological history at various time levels and, in Hurst's opinion, as mutants. Since he regards the species as composed of many homozygous dominant specific characters, many mutants are required to form a new species. These mutants undergo selection while the climate may pass through extreme changes in different geological periods. Ultimately the new species will have to attain some degree of sterility.

Genetics and Paleontology. Several instances of the apparent compatibility of paleontological and genetical knowledge have been presented thus far. Two additional cases may serve to illustrate the successful transfer of genetical concepts into paleontological theory and interpretation. Axelrod (1941) in the course of paleobotanical studies of Tertiary floras found it useful to apply the concept of ecospecies to the fossil equivalents of modern endemic trees and shrubs, which occupied habitats widely differing from those occupied by their nearest descendants. The modern endemics survived in habitats different from those occupied by their related fossil forms as a result of the elimination of biotypes during the late Cenozoic. Mason (1942) suggests a similar interpretation for the extremely localized populations (or species) of Ceanothus found in certain parts of northern California.

The other case is based on the demonstration by Wehrli (fide Weigelt 1942) of geographical races among the fossil horses of Europe. So far the European representatives of Anchitherium have been classified as *A. aurelianense* which lived in central and western Europe for about two to three million years. These forms range through the whole Miocene and Lower Pliocene. Wehrli was able to work out a good phylogenetic series based on tooth characters. The significant thing is that evolution along this line progressed more rapidly in France than in southern Germany, e.g., the French race gets larger more rapidly than the dwarf

type of southern Germany and Switzerland. Contrary to the views held by Stirton (1940) et al., Wehrli claims that American fossil horses of Kalobatippus and Hypohippus are indistinguishable from the European forms of *A. aurelianense*. All told three stocks were found and recognized, namely small, normal, and large, but were retained in *A. aurelianense*. The American species *A. matthewi*, more appropriately designated as *Megahippus matthewi*, apparently branched off from the large stock and attained giant size which was never reached in Europe. Here is a fine example of the presence of parallel lines of evolution pointing in the same direction but followed through at different rates. Most likely similar cases can be found in the literature or may become known as certain localities are worked intensively.

Finally we may turn our attention briefly to another frequently voiced opinion which is held by those who are apparently unwilling to interpret the fossil record correctly. According to these authors (Bertalanffy and particularly Frieling 1940) the evolution of the major groups has come to an end and only genera are developed anew or often only species (Bertalanffy 1937). Frieling limits evolution to intraspecific processes which are the only ones possible at the present, because speciation stopped with the advent of man. Such claims are obviously ill founded and outside the domain of biological science.

As should be evident from what was said regarding the time factor, evolution progresses in different groups at different rates. But it is difficult to see, why it should have come to an end at the present time. In fact, Ritchie paints a rather gloomy picture of the future of mankind as we try to look ahead as far as we can look back into man's past. Here, at least, he seems to have the evidence on his side.

The foregoing discussion of the kinds of species recognized today, of the various modes of origin known and of the speeds with which they progress, clearly shows the great variation of the existing mechanisms of evolution "even from genus to genus, so that it is becoming increasingly difficult to formulate general 'laws' of evolution, and the universal applicability of such 'laws' as have been derived from paleontology and morphology is becoming more and more doubtful" (White 1937).

But in all this flux limits are set preventing further changes. In this sense evolution is a process of "sequential stabilization of genetic patterns," as Ferris (1943) puts it, involving "loss and limiting of capacities as well as the attainment of them."

Summary. The term species is applied to groups of very different ecological and genetical status. As a result speciation must progress by various modes and definitely at different rates. Examples of estimated and known rates of evolutionary processes affecting both higher and lower systematic categories are presented, including cases of slow (modern horse) as well as rapid evolution (by mutator genes, ploidy, etc.). The compatibility of genetical and paleontological knowledge is also demonstrated. Although the occurrence of unstable genes, mutation rates, hybridization, ploidy, etc., are admittedly not the only effective evolutionary factors, they represent some of the most important agencies

and indicators of evolutionary changes. The rates of evolutionary processes differ so greatly that they can not be expressed in simple mathematical terms.

Acknowledgment

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[4] For additional examples the reader is referred to Chapter 25, Rate of Evolution and Speciation (pp. 383-396) of *Foundations of Plant Geography*, by Stanley A. Cain, Harper & Brothers, New York, 1944, and the *Report of Meetings of the Committee on Common Problems of Genetics and Paleontology*, National Research Council, Division of Geology and Geography, Washington, 1943 (15 pp., mimeographed), which came to the writer's attention while the present paper was in press.

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BACTERIOLOGY

Chairman: L. S. McClung, Indiana University

The Bacteriology Section met with the Indiana Branch, Society of American Bacteriologists.

Dr. Lyle A. Weed, Indiana University Medical Center, was elected chairman of the section for 1944. Dr. C. M. Palmer, Butler University, was elected vice-chairman.

A comparison of the action of sulfa-drugs on the growth of a bacterial virus and of its host. M. Delbrück and S. E. Luria, Vanderbilt University, Nashville, Tennessee, and Indiana University.—These experiments were performed to attempt to dissociate the growth of bacterial viruses from the growth of their host by blocking certain enzymes of the bacterial cell. The growth of both host and virus in a synthetic medium was quantitatively studied, and the action of sulfathiazole (ST) investigated. As shown by previous authors, ST(10^{-6}–10^{-5}M) reduces the bacterial growth rate after a latent period of a few hours. Whether the growth continues at this reduced rate or is replaced after a few hours by rapid death of bacteria depends on the size of the initial inoculum. Para-aminobenzoic acid (PAB) inhibits the action of ST; the antagonism is strictly quantitative. Normal growth takes place with ratios PAB/ST higher than 1/7. The experiments on the effect of ST on virus growth, as yet incomplete, show a strict correlation between inhibition of bacterial growth and of virus growth; this is reduced in the same proportion as is the growth rate of bacteria. The reduction in virus growth takes place only when the host has been grown in presence of ST long enough to show an appreciable reduction of its growth rate. Possible interpretations of these results in connection with the role of bacterial enzymes in the growth of virus are suggested.

War-time immunization. W. A. Jamieson, Lilly Research Laboratories.—The most recent methods of preparation of vaccines against cholera, plague, yellow fever and typhus fever are described. These vaccines are of particular interest for troops leaving the United States.

This laboratory has made its greatest contribution to the immunization program of the war effort in the preparation of typhus vaccine. Different forms of typhus vaccine preparation will be presented, and the current fertile egg method will be dealt with in some detail. Methods of assay of typhus and other vaccines in the laboratory, also primary and re-immunizations as developed during the last year or two, will be referred to.

Dissociation of the growth of bacterial viruses and of their host by means of temperatures above optimum.[1] S. E. Luria, Indiana University.

[1] Experiments done in the Department of Biology, Princeton University, under the tenure of a Guggenheim Fellowship.

—For two coli-viruses, temperatures between 15° C and 40° C affect the growth of both host and virus in a strictly parallel manner. At temperatures of 43 and 45° C the bacteria can grow at reduced rates; if, however, bacteria infected at 37° C are transferred to 43 or 45° C, no liberation of virus takes place. If the bacteria are then returned to 37° C, virus is liberated, in small amount, and after a delay increasing with increased stay at high temperature. These results seem to suggest that one or more of the reactions involved in the production of new virus are inhibited at or above 43° C. The inhibition must take place through a reaction with a very high temperature coefficient. Some essential reagent is probably removed or inactivated, as indicated by the delay and incompleteness of the restoration of virus production after return to normal temperature. There is as yet no indication as to whether the inhibition concerns the actual multiplication of the virus in the host or only its liberation from the host (lysis).

Effect of various concentrations of iron on the production of riboflavin by certain clostridia. ALLEN SAUNDERS *and* L. S. MCCLUNG, Indiana University.—In a study of riboflavin production by various aerobic and anaerobic bacteria, Rodgers (1942) reported that fortification of the iron content of the corn mash used for fermentation by *Clostridium acetobutylicum* increased the production of riboflavin. Confirmation of this stimulatory effect of iron has been noted in the case of 4 out of 5 strains of this species in corn mash fermentations to which Fe as $FeSO_4$ was added in 2, 4, and 6 x 10^{-6}M concentrations. The effect appears restricted to *C. acetobutylicum*, however, as *C. roseum*, *C. felsineum*, and other pigmented anaerobes including certain yellow butyric types do not respond to the addition of iron.

Natural bactericidins in the plasma of the domestic fowl. E. E. SCHNETZLER, Purdue University.—The plasma of the domestic fowl contains natural bactericidins capable of killing *Salmonella pullorum* organisms. Wide differences in resistance to the bactericidal action were found between the eight strains of *S. pullorum* employed. Those strains that had been isolated most recently were more resistant to bactericidal action. However, there was considerable variation between the strains within this group.

The plasma of White Leghorns of two different strains showed higher bactericidal activity than that of Rhode Island Reds and White Rocks. The greater bactericidal action of the plasma of White Leghorns may partially account for less infection being observed in this breed.

Wide differences in bactericidal activity have been found between fowls of a given strain. These wide differences observed among stock reared in the same flock indicate genetic differences. After three generations of selection two lines of Rhode Island Reds have been produced differing in bactericidal activity. The results obtained indicate that the bactericidal action is in part at least influenced by heritable factors.

The bactercidal action of the plasma apparently involved a natural antibody and complement. The plasma of fowls showing low bactericidal activity was apparently not deficient in complement.

Recent Developments Concerning the Anaerobic Bacteria and their Activities, with Particular Reference to the Tetanus and Gangrene Organisms*

L. S. McCLUNG, Indiana University

Although anaerobic bacteria were recognized much earlier and some studies of their importance had been made, it was not until the time of the first world war that sufficient impetus was given to these investigations to bring forth proper methods of study and a clear picture of their relationship to disease and certain processes in the economy of nature. By 1918 there were available techniques for the isolation and study of an anaerobe though some of the techniques now appear clumsy and open to question. The tetanus organism had been isolated and correctly associated with disease and some of the gangrene organisms had been recognized. The antitoxin for the tetanus organism was available for prophylactic or therapeutic purposes but the toxin of the Welch bacillus had been obtained only recently and the possibility of the preparation of an antitoxin investigated. The Weizmann process for the production of butyl alcohol and acetone by anaerobic fermentation of starchy materials was an outgrowth of the need during the war for acetone for the manufacture of explosives. In 1919 Burke, on the basis of toxin neutralization (by antitoxin) studies, divided the botulinus group into two types.

Many advances have been made concerning these organisms since 1914-18 and it may be of interest to summarize certain of the important relationships. Since limitations of time will not permit the historical development of any of the topics, only the most recent research will be discussed and for the same reason only certain topics will be chosen for discussion. Since the literature on the anaerobic organisms accumulates roughly at the rate of seven hundred and fifty to one thousand papers per year, obviously only a fraction of these may be discussed. Those interested in additional material are referred to the subject bibliography of the literature on these organisms (78, 80). A recent monograph (155) is devoted to the anaerobic bacteria but unfortunately it lacks conciseness and may also be criticised for the inclusion of much material reported in the literature which has not been accepted by other investigators.

Methods and Media for the Study of Anaerobic Bacteria

There have been several recent advances in the techniques for the study of anaerobic bacteria, and through these the technician in the laboratory is now able to work with the anaerobes almost as quickly and easily as with the aerobic types. These and older methods are given in detail in the new edition of Leaflet III of the Manual of Methods of

* Address of the retiring chairman of the Bacteriology Section.

Pure Culture Study (75), but it may be well to discuss briefly some of the newer techniques. One of the oldest systems for securing an anaerobic environment made use of the absorption of oxygen in the reaction between pyrogallic acid and alkali. Spray (139), using this reaction, designed a deep bottomed petri dish which has a ridge across the center to keep solutions of the two chemicals separated until the top and bottom of the dish are sealed together by tape or plasticene. Thus each dish is a separate unit. The Pyrex dish, called the Bray dish, is similar to the original Spray dish and is to be preferred. Another single plate system, which was described only recently by Brewer (14), has much to recommend it. This consists of a special top of heavy glass and the design of the dish is such that the top of the dish rests, at its periphery, on the agar medium (in the bottom dish) to form a seal, and the remainder of the dish is slightly raised. Thus only a small amount of air is trapped over the surface of the agar and this is removed by means of the reducing action of the medium. For satisfactory use of these dishes a medium of high reducing capacity is necessary such as that, supplied by the Baltimore Biological Laboratories, in which sodium thioglycollate and sodium formaldehyde sulfoxylate are incorporated. Vera (149) has found the plate quite useful in the demonstration of hemolysis by anaerobic bacteria.

A recent reintroduction has been made by Marshall and Nordby (85) of the use of an aerobic organism to utilize the oxygen and provide anaerobic conditions for single plate cultures. The system proposed uses small plates for the aerobic organism which are pressed down into the agar of the regular plate and this latter plate is inoculated with the anaerobic species. The aerobic organism uses the oxygen in the small area enclosed between the surface of the two agar plates.

For the incubation of a number of tubes or plates of the ordinary type there is now available a jar made in this country called the Brewer jar (17) which is similar in principle to the McIntosh and Fildes jar which was originally available only in England. An advantage of the Brewer jar is that ordinary illuminating gas may be used in place of hydrogen for flushing the jar prior to combustion. It is not difficult to manipulate and its purchase is suggested to those who have a large number of anaerobic plates in routine use.

Rosenthal (122) has proposed another method for securing anaerobic conditions based upon the liberation of hydrogen by the action of sulphuric acid on powdered chromium. This is an easy system for the production of hydrogen and the ingredients for the reaction are usually available. Miles (89) objected to the method on the basis of the probable evolution of a gas, possibly hydrogen sulphide, which was toxic to certain important organisms. Mueller and Miller (93) modified the original method by including sodium carbonate to liberate carbon dioxide and their system is sufficiently simple to merit mention. Either a desiccator equipped with a stopcock to provide for escape of the gases or a two quart fruit jar with a metal casting of the lid to which is attached an escape spout may be used. For the fruit jar one gram of sodium carbonate and three grams of powdered chromium (98% pure) are placed

in the bottom of the jar after which the cultures are added, and then 30 ml. of a solution (15% by volume) of sulphuric acid are introduced by means of a funnel. The lid is clamped on immediately. Directions are included in the original paper for a simple mercury trap which allows escape of the gases and yet prevents inflow of oxygen.

With reference to special media for anaerobic organism in recent years we note a growing use of liver infusion (77, and others) for the enrichment of many species particularly for the types producing butyric acid and butyl alcohol and for one of the thermophilic species which is involved in the spoilage of canned foods. It is probable that the success of the liver infusion for these organisms relates to the need for certain growth factors which are supplied by the liver tissue. A very inexpensive medium, simple to prepare, for use for general purpose was suggested (77) which combines the growth promoting qualities of the liver tissue with the semisolid nature of 5% corn meal mash. The finished medium has the virtue of remaining anaerobic for extended periods even without special seals at the surface to protect the medium from absorption of oxygen.

One of the most notable of advances in late years in the problem of the easy cultivation of anaerobic species is the proposal by Brewer (12, 13) of the use of sodium thioglycollate in liquid media to serve as the major reducing agent in the "aerobic" cultivation of anaerobes. Other compounds including thioglycollic acid had been proposed for the same purpose but most of these were thermolabile and hence it was necessary to add these to the media aseptically following sterilization. The sodium thioglycollate is, however, heat stable and may be incorporated with the other ingredients at the time of preparation of the medium. Brewer also proposed a nutrient base medium containing the reducing agent and a small percentage of agar, and claimed that the medium could be used successfully without a special anaerobic seal. With the exception of certain specialized meat infusion media and a few others the practice of "open" incubation of anaerobic media had not been practiced generally for most media become reoxidized almost immediately after sterilization. The claims of Brewer have been fully substantiated. Marshall, Gunnison and Luxen (84) found the medium suitable for sterility testing of biological products. The National Institute of Health recognized the use of the medium for this purpose (35). McClung (73, 76) showed that the new medium compared favorably with meat infusion and other media for the enrichment of *Clostridium welchii, C. septicum, C. tetani* and other pathogenic species when only a small number of cells were present in the inoculum. Further it was found (74) that the use of sodium thioglycollate aided in the problem of a suitable medium for organisms with a long lag period and in the preparation of large volumes of certain anaerobic cultures. Others (7, 30, and 102) have discussed the problem of the neutralization of mercurials by the medium. Mollov, Winter and Steinberg (90) claimed distinct advantages for the use of thioglycollate media in routine blood and post-mortem cultures involving the isolation of strains of pneumococci and streptococci. Brewer (15) has proposed an adidtional compound, sodium formaldehyde sulfoxylate, is

a reducing agent but to date no other studies concerning this compound have appeared.

Spray (140) has published an extensive paper on the use of semisolid tubed media in the study of anaerobic species in which he has shown that the addition of a small percentage of agar is sufficient to prevent the immediate reoxygenation of the media following the reduction in oxygen potential which occurs during heat sterilization. With this aid he has proposed formulae for media for physiological reactions which may be inoculated and incubated without a necessity of placing the tubes in an anaerobic jar or using a seal of vaseline or other material at the surface of the liquid in each tube. The convenience of this method when it is compared with some of the older methods is not easily underestimated. Unfortunately the scheme of species identification which was proposed by Spray involves a two week incubation for completion of certain of the differential reactions. Reed and Orr (118) have combined the semisolid agar technique of Spray (140) with the thioglycollate reducing agent of Brewer (12, 13) to good advantage and have proposed formulae of new media and a system of rapid identification of the gas gangrene anaerobes. Their paper is recommended for study by all who deal with this problem in the clinical laboratory.

Accessory Growth Factors and Synthetic Media Problems

One or more accessory growth factors were early shown to be required by *C. sporogenes* (65), *C. botulinum* (36), members of the butyric-butyl group (111, 161), non-sporulating types (157, 158), and possibly other species. Of special interest in this problem are the recent reports concerning *C. tetani* and *C. welchii.* A study of the possibilities of growth and toxin production on synthetic media were, as we shall see later, incident to investigations on the proper media for the production of toxoids.

As an extension of his studies on the nutrition of the diphtheria bacillus, Mueller and his associates initiated a series of very fruitful investigations. In 1940 (91) it was reported that tetanus toxin could be produced on a simplified medium. Mueller and Miller (92, 94, and 95) later obtained growth on a medium composed of the usual inorganic elements, an acid hydrolysate of protein, tryptophane, adenine, or hypoxanthine, pantothenic acid, thiamine, riboflavin, "folic" acid. Biotin was listed as probably being essential. Another contribution (96) gives the formula for the production of tetanus toxin in a peptone free broth. With mice the potency was in the range of m.l.d. = approximately 160,000. For this the nitrogen source was a dilute casein hydrolysate and to this were added appropriate amounts of the following: (1) Accessories and metals mixture containing magnesium sulphate, traces of copper, manganese, and zinc, and nicotinic acid, beta alanine and pimelic acid, (2) cystine, (3) tryptophane, (4) glucose, (5) calcium pantothenate, and (6) liver eluate. As with the diphtheria bacillus the concentration of iron was shown to be a critical factor and directions for removing the excess iron were included.

The problem of the production of *C. welchii* toxin on a simplified medium has been attacked by several investigators. Basu and Sen (3), using a veal infusion broth, were able to produce filtrates with the average m.l.d. stated to be 0.00005 ml. for a 350 gram guinea pig. Taylor and Stewart (147) proposed a medium of Bacto-peptone, casein, potassium bicarbonate, ammonium dihydrogen phosphate, disodium hydrogen phosphate, ferric ammonium citrate, and glucose. Seal (127) used a digest of veal and fresh beef liver.

Tamura, *et al.* (145, 146) have given information on the production of *Clostridium welchii* toxin in a peptone free" medium. An acid hydrolysate of casein was used with addition of various salts, tryptophane, panthothenic acid, riboflavin, nicotinic and pimelic acids and biotin. Again it was shown that minute concentrations of iron influenced the production of toxin.

Species Identification Reactions

Of major importance and interest are reactions or a small group of procedures which enable the laboratory technician to make a rapid identification of a new isolation. These are perhaps of special importance in the identification of members of the gas gangrene group. What procedures are available for use with important species of the genus *Clostridium*? We have mentioned earlier the general identification outlines proposed by Spray (140) and Reed and Orr (118). An earlier procedure, proposed by Hall (54), gave considerable emphasis to the morphology of the spore. In addition to these general tests, and others such as characteristic pathology observed in artificially infected animals, there have been proposed, though not as yet universally accepted, certain specific procedures which merit brief discussion.

The "stormy milk" fermentation for the identification of *C. welchii* doubtless is familiar to all. It has been noted by several workers that this reaction alone must not constitute a complete diagnosis due to the fact that certain other species, principally motile butyric acid and butyl alcohol producing species also may give a "stormy fermentation" of milk particularly if the inoculum contains a considerable number of cells. These are differentiated by positive motility and by inability to produce toxin. Robinson and Stovall (121) proposed that the reaction could be made more specific if 1.0 ml. of 20% Na_2SO_3 and 0.1 ml. of 8% $FeCl_3$ were added to each 10 ml. of milk and noted that in the modified medium *C. welchii* gave a blackening reaction.

It may be remembered also that the English bacteriologists Wilson and Blair in the early 1920's proposed a bismuth sulphite medium for the recognition of *C. welchii* in contaminated water supplies. Lyons and Owen (71) have examined the possible use of this medium in the clinic. According to them the Wilson-Blair medium is a useful diagnostic aid in the early recognition of the presence of certain clostridia in wound exudates but has the disadvantage that there is no correlation between toxigenicity and the production of the characteristic reaction.

Another specific reaction, generally termed the Nagler reaction, has been proposed for *C. welchii* which has aroused considerable interest.

In 1939, Seiffert (129); in Germany, and Nagler (99) from Australia, independently reported that a mixture of *C. welchii* toxin and normal human serum produced upon incubation of a characteristic opalescence. Mcfarlane, Oakley and Anderson (81) believed that this opalescence was due to the liberation of insoluble fatty material from the serum and showed also that a dilute solution of egg yolk, called lecithovitellin, could be substituted for the human serum. Nagler (100) agreed that this substitution was satisfactory and also used the reaction as an indicator in toxin-antitoxin titrations. Oakley and Warrock (103), Seal and Stewart (128) and Stewart (142) are others who have used the reaction. Hayward (57) modified the reaction by the use of a fluid Nagler test medium into which isolated colonies from the original sample plating could be picked. Thus it was claimed that certain identification of *C. welchii* could be completed within 40-48 hours after plating of the original sample. Hayward reported also preliminary details of the use of the reaction with solid media and extended these observations in the Medical Research Council's War Memorandum No. 2 (87). In her latest paper (59), there is a critical examination of the specificity of the plate reaction and a recommendation of the plate method for the routine examination of wound and puerperal swabs from patients suspected of having anaerobic infections. Certain streptococci and a few aerobic and anaerobic spore-bearers also give zones of opacity but the formation of these is not inhibited by antitoxin. The *Sordelli-bifermentans* group give zones which are neutralizable by *welchii* antitoxin but these reactions are usually feeble. Further, these organisms may be differentiated from *C. welchii* by the presence of spores on 24 hour plate cultures and by failure of lactose fermentation.

When considering the Nagler reaction it should be noted that Weed and his associates (151, 152, 153) have questioned the specificity of both the reaction of *welchii* toxin with lecithovitellin and of its neutralization by *welchii* antitoxin. They contribute evidence to show that the flocculation develops as a result of acid production during growth and that many species, both aerobic and anaerobic, would cause a reaction. Hayward (59) believes that the results obtained by Weed and associates are due in the main to peculiarities of the broth media which they used. Although the final word on the suitability of the Nagler reaction as a specific diagnostic test for *C. welchii* must be delayed until Weed has had an opportunity to examine his data in the light of the suggestions of the English workers, it seems possible that out of the controversy there may arise a test which will be of value in the clinic.

A different type of a cultural reaction was proposed by Gordon and McLeod (50) as a simple and rapid method for distinguishing *C. novyi* (*C. oedematiens*) which is another of the gas gangrene anaerobes. On a medium containing benzidine and a peroxidase they noted a blackening reaction which they recommended as a useful method of identification of *C. novyi* in pathologic material. It was claimed that the only other organisms which were found to produce the blackened area were *C. botulinum* and some strains of anaerobic streptococci. Hayward (58), however, did not confirm these data but found several organisms were

capable of producing the blackening and some of these were difficult to differentiate from *C. novyi.* Further, all colonies of *C. novyi,* even from a virulent strain, did not always produce the characteristic blackening. These observations of Hayward are in agreement with some observations in our laboratories (113), so we must conclude that, at the present at least, the reaction proposed by Gordon and McLeod should be used with caution.

The last suggestion concerning recognition of the toxin producing species of *Clostridium* has appeared only recently from the English group. Petrie and Steabben (112), using as a base medium a glucose horse-meat infusion broth made with Evans peptone, added to this medium, immediately prior to pouring, an amount of the appropriate antitoxin to give a final concentration of eight international units per ml. A zone of precipitation occurs around the colony. Using antitoxin for the different species in separate plates early recognition of the various organisms was claimed.

Serological Studies with Anaerobes

In comparison with the knowledge of the 1918 era we have come a long way on the road in the late years. To date, however, I cannot claim that either the precipitin reaction or the complement fixation have contributed much useful information with the anaerobic species, but there is quite a different story with regard to the agglutination and the toxin-antitoxin reactions. We have reviewed (79) the entire story but it may be well to outline some of the advances here and to consider more recent material.

With regard to the agglutination reaction, in my opinion, the possible usefulness of this test has increased considerably following the recognition that it was possible to differentiate the somatic and flagellar antigens of motile anaerobes in a manner similar to the well known studies on the enteric organisms. No claims have yet been made that these reactions are useful in the diagnosis of anaerobic infection in which the serum of the patient would be used but the considerable data of importance have accumulated with reference to the study of pure cultures of certain species.

The results with *C. tetani* are especially interesting. It was early shown that subgroups of the species existed on the basis of the flagellar antigen and Gunnison (52) in a study of 67 strains found evidence for nine groups (and a tenth has been added later). Further, the results indicated the presence of a common O antigen which showed no type specificity. Certain of the groups established on the flagellar antigen reactions showed an additional O antigen. Related species did not possess the O factor for *C. tetani* and it was shown that certain atoxic strains could be recognized by their reaction in serum prepared from a known strain.

Subdivision of *C. septicum* on the basis of agglutination reaction also relates to the flagella antigen. At least four, possibly six, groups are apparent (4, 31). Cross reactions with the O antigens of these groups

reveal close relationship but not identity of the factors. The somatic antigen fraction of *C. chauvoei* likewise appears distinct and offers possibilities of a method of separation of this organism.

C. parabotulinum is another species in which we find (72) subdivisions based upon the flagellar antigens whereas there seems to be a somatic antigen common to all strains. Some cross reaction is obtained with *C. sporogenes*, but a *parabotulinum* serum pre-absorbed by *sporogenes* offers distinct possibilities as a reagent for species diagnosis.

What of the agglutination of *C. welchii*—one of the most important species of the genus? There were early claims that it was impossible to produce an agglutination antiserum for this organism. It should be remembered that this species is non-motile and should show reactions only in the somatic series. Late experiments show that this is true and several investigators (62, 154, 160) have been able to obtain satisfactory titers. It seems, however, that there are a number of subgroups (104) and to date no useful aid has been suggested as a result of the new data.

All of the available evidence indicates that the species *C. tetani*, *C. septicum*, *C. histolyticum* are monotypic with respect to toxin formation. That is to say, the antitoxin from the toxin of any strain will neutralize the toxin of any other strain. This simple story is, however, not the case with *C. welchii*. On the basis of non-cross neutralization tests it is now recognized that there are four groups within the organisms having physiological reactions similar or identical with the organism known as *C. welchii*. These were proposed first as distinct species being called—*Bacillus agni*, *Bacillus paludis* and *Bacillus ovitoxicus*. Wilsdon (160), however, studying representatives of each of these has concluded that it would be better to consider these as representing four toxin types within the same species, in as much as the differences in physiology between these organisms were considered to be of minor importance. These are now generally known as Type A, B, C, and D of *C. welchii*, or *C. perfringens* if you choose to follow the latest edition of Bergey.

It is important to note that thus far only toxin Type A has been associated with gas gangrene in man whereas the other types are the agents of various animal diseases. Type B is concerned with an enterotoxemia of young sheep and has been called the lamb dysentery bacillus. Type C was recovered from another sheep disease called *struck* which seems localized in England. The last organism Type D has its origin in animal disease also being associated with enterotoxemia of sheep in West Australia and a disease aptly termed "pulpy kidney".

A great deal has been written on the fractionation on basis of physiological reaction of the toxins of these four types and it seems likely that the entire picture is not yet completely clear. The majority of the early literature was reviewed in 1938 by McCoy and McClung.

But one of the gangrene organisms yet remains for discussion. This one was not described until 1922 and has had a rather checkered history since then. Originally described by Sordelli, it was given a trinomial name, *Clostridium oedematis sporogenes* which name, being invalid, was changed to *Bacillus sordelli*. Other workers isolated in this country a gangrene organism from a post-operative infection (and also the catgut

used) to which they gave the name *Clostridium oedematoides*. There now seems to be no question but that these organisms are identical but lately there seems reason to suspect that this pathogenic species may be closely related to, if not identical with, the non-pathogenic species *Clostridium bifermentans*. This question is now being considered in our laboratories with a collection of authentic strains collected from the original authors or other official sources.

To turn back to the 1918 era for a brief moment it will be recalled that Burke in 1919 subdivided the organisms producing the botulinus toxin into two groups or types—designated A and B. We now find that this type differentiation has been extended to five (A through E) and that a new advance is the recognition of the fact that two widely divergent physiological types are concerned (See 79 for literature citations). Some of the strains are proteolytic while others are non-proteolytic. The majority of the strains of American origin are in the former group, but it should be noted that recent cases of the disease in America were thought (40, 60) to have arisen from Type E toxin—a type known previously only from Russia. This may account for failure of therapeutic use of antitoxin in some cases since the majority of this is produced against only Type A and Type B toxin. The Type E organism is non-proteolytic, somewhat difficult to grow, and not so greatly heat resistant. A very real problem is presented to the laboratory in the isolation of this organism from sample material. Thus far the best procedure concerns itself with the identification of the toxin from the original sample by means of animal protection tests.

So much for the laboratory study of the organisms and their reactions. Let us now consider briefly a few other points. Perhaps the greatest advance since the time of the last war with reference to the anaerobic infections and intoxications relates to the successful use of injection of toxoid as a means of stimulation of active immunity against tetanus. At the present time there is available both plain toxoid and alum precipitated toxoid for this purpose. We note that the French, Italian, American and probably the German armies have instituted tetanus toxoid injections for all and the British have it available though the vaccination, as is usual, is not compulsory. At least in the American Forces the Navy and Marine Corps are similarly protected. In this country there is divided opinion among the forces as to the type of toxoid to be used (31, 101, 132, 133)—the Army using plain or liquid toxoid whereas the Navy and Marine Corps specify alum precipitated toxoid. Regardless of this divergent opinion there is ample evidence that toxoid injections are effective in stimulating a basic immunity which should be effective in preventing the disease (25, 32, 45, 63, 86, 109, 110, and others).

Usually the routine consists of two injections of toxoid two to three months apart and then a third "booster" or "recall response" dose is given after a considerable period (144) or in the Armed Forces just prior to the entrance of the person, who is receiving the injections, into an active combat zone. Gold (46, 47, 48) has advocated the stimulation of active immunity by the combined subcutaneous and intranasal routes. Tetanus toxoid may be combined with typhoid vaccine (37, 51, 83, 115,

116), with diphtheria toxoid (5, 24, 38, 117) and the suggestion has also been made (108, 143) that gangrene and tetanus toxoid may be combined.

In addition to its use in the Armed Forces it may be noted that toxoid immunization has been recommended for children and for allergic individuals (38, 39, 67, 109, 110, 148) and others who may be exposed to probable sources of infection. It would seem that a sound basis exists for its use rather than the possible sensitization of large groups as a result of prophylactic injections of antitoxin. It must be remembered that tetanus is not confined to injuries following battle wounds but that it does occur also in civilian life.

Of importance is the question that has been raised concerning the production of toxoid from a toxin produced on a medium containing peptone (particularly Witte peptone) due to the sensitization which may result (2, 16, 26, 49, 105, 114, 123, 159). This has been satisfactorily answered for other media are now available which do not contain peptone, and it is claimed (16) that the use of alum precipitated toxoid avoids sensitization. In particular we would mention again the work of Mueller and associates who have shown that toxin produced on their peptone free medium can be converted to toxoid (126) and further that such toxoid is antigenic (97, 98). Fraser, *et al.*, (37) also show that toxin prepared on peptone free media can be used without the production of anaphylactic reactions. It has been recommended, however, that skin tests for sensitivity be employed routinely and/or that adrenaline or epinephrine be kept at hand whenever injections are made.

A means of solving the question of avoiding serum reactions following the use of the usual equine antitoxin in prophylactic injections has been considered also. Glaser (41, 42) has proposed the use of bovine antitoxin for this purpose while Schaeffer and Myers (125) successfully treated a patient with a despeciated antiserum. The antitoxin in the latter case had been subjected to partial digestion by takadiastase.

The possibilities of the production of an effective toxoid with *C. welchii* toxin has been investigated. Laboratory studies with animals are in the affirmative and it may be expected that these results have been extended to man but to date extensive studies on this have not appeared (66, 106, 107, 142).

What of other means of protection against these anaerobic infections or of treating them? One thinks, of course, of the sulfonamide drugs as chemoprophylactic and chemotherapeutic agents. Sulfonamide drugs are now supplied in sterile form to each U. S. soldier who is instructed to dust the material in wounds, his own or of others, if medical aid is not immediately available following injury. Local treatment seems more effective than oral but the results are complicated due to the fact that the various species of anaerobes differ in their sensitivity to these drugs (6, 8, 19, 21, 23, 53, 56, 68, 70, 82, 119, 134, 135, 141) and to zinc peroxide which has been proposed also (88, 120). There is some evidence perhaps contrary to what you would expect, that these drugs are contraindicated when serum therapy is instituted.

Sterile drugs were mentioned above. Peculiarly there exists the possibility that the drug itself might be contaminated at times and would

thus introduce rather than prevent an infection (1, 156). Adequate means, however, are now available for heat sterilization of the sulfonamides (18, 22, 69).

X-ray has been proposed as a beneficial diagnostic and therapeutic aid for gas gangrene and several reports have appeared concerning this topic (9, 10, 11, 20, 27, 33, 43, 44, 55, 124, 130, 131, 136). Not all the evidence is in favor of the therapeutic value (20, 28, 137, 150) though Kelly (64), the main proponent of its use presents a convincing summary of his and other work. The increase of gas in the tissue in early stages of the infection following an injury as revealed by successive x-ray pictures would seem a valuable aid in diagnosis. In this regard it must be remembered that the diagnosis of gangrene must often be based largely on clinical evidence, not bacteriological, due to the time required for the results of bacteriological tests and also since it has been shown that *C. welchii* may exist in a wound which shows no evidence of gangrene (61, 138).

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A Technique for the Production of Immune Sera for Paramecium aurelia

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In connection with studies on the inheritance in certain ciliate protozoa (5) which are being conducted by Professor T. M. Sonneborn at Indiana University, it was desirable to produce immune sera against *Paramecium aurelia*. Some of the phenomena which were being studied suggested that a fractionation of antigens in a manner similar to separation of the somatic and flagellar antigens now widely used with bacteria might be interesting and worthwhile. Such proved to be the case and this paper will outline the technique, which was developed in the fall of 1941, by which we were able to produce satisfactory sera.

The following variations in the preparation of antigen and in the routine of injection were studied in the original and later series of animals:

(#1) Six intraperitoneal injections of 3-4 ml. of a thick suspension of organisms (approximately 75,000) were given at weekly intervals.

(#2) Six intraperitoneal injections of 3-4 ml. of a thick suspension of organisms (approximately 75,000) were given twice weekly.

(#3) Six intravenous injections of a thick suspension of cells which had been steamed for 1 hour in the Arnold sterilizer, were given twice weekly.

(#4) Six intravenous injections of the *supernatant fluid* obtained by centrifuging a culture which had been mechanically agitated in a manner to be described, were given twice or thrice weekly.

(#5) Six intravenous injections of the culture mechanically agitated prior to centrifugation, were given twice weekly.

In (#3), (#4), and (#5) the amounts of the successive injections were approximately as follows: 0.25, 0.5, 0.75, 1.0, 1.0, and 1.0 ml.

In all experiments healthy adult rabbits were used to produce the serum. In no instance did we encounter a normal serum which displayed any reaction when mixed with untreated paramecia. All samples were heated at 55-60° C. for one half hour before using. Beginning on the fifth day or six day after the last injection, all animals were bled for trial titer, and, if found to be satisfactory, additional blood was obtained on succeeding days by marginal ear vein bleeding. The serum was

removed from this blood after overnight refrigeration and stored, without preservation, at 4° C., in rubber capped serum vials or in sterile small screw-capped bottles. Small quantities of serum were withdrawn as needed from these stock bottles, heated in a waterbath at 55°-60° C. for one-half hour, and dilutions prepared for the tests using the solution suggested by Bernheimer and Harrison (1).

The paramecia used for the injections were grown by Professor Sonneborn and collected in the following manner. The races to be used were transferred from stock bottles to 250 ml. flasks containing approximately 100 ml. of lettuce infusion (4) to which pure cultures of *Aerobacter aerogenes* were added to serve as a source of food. The cultures were maintained at a temperature of 27° ± 1° C. It was unnecessary to handle the flask cultures aseptically. Each culture was used when 3-5 days old. At the time the paramecia were to be used, they were aggregated in a dense ring immediately below the surface of the fluid and around the contact between fluid and flash. This dense ring of paramecia was withdrawn from each flask with a pipette to which a rubber bulb was attached and the collections from a number of flask cultures of the same race were combined until 20 to 40 ml. were obtained. The combined material was then centrifuged at approximately 1500 r.p.m. for 15 minutes and the sediment resuspended in approximately 5 ml. of liquid.

In techniques #4 and #5 the material was given further treatment before injection. The suspension was drawn into and expelled from a syringe, fitted with a fine bore (#22 gauge) needle, for a minimum of 25 times by which time the paramecia were broken into small fragments. For technique #4 this material was then centrifuged for 1-2 hours at 3500 r.p.m., and the *supernatant fluid* used for injection. This represented an attempt to approximate the conditions previously found to be successful for preparing flagellar suspensions of bacteria (3). microscopic examination of this supernatant material revealed numerous separate cilia. For technique #5, the culture was mechanically agitated but not centrifuged.

Results

As discussed by Bernheimer and Harrison (1) and others, the criterion for judging the activity of a serum is based upon a phenomen called an "immobilization reaction". When fresh, living paramecia are mixed with an immune serum there is a disturbance in the rate of locomotion of the animals. In low dilutions of a potent serum, complete immobilization and sometimes death of the paramecia may be observed within a few minutes. In more dilute solutions of the serum, the paramecia become immobilized more slowly and may show spontaneous recovery after a few hours. Higher dilutions of the sera may produce only a retardation of locomotion. We have taken as the titer of a serum that dilution which showed a definite slowing of locomotion of fresh paramecia at the end of a two-hour period. The animals were mixed with the diluted serum in small concavities in thick slides and the mixtures incubated at

27° ± 1° C. All observations on presence or absence of locomotion were made with a wide-field binocular dissecting microscope.

Of the five variations in technique which were tested the best seems to be the injection of the supernatant fluid from the mechanically agitated culture. This material contained a large number of cilia but relatively few, if any, intact cells. By this technique it has been possible to produce with regularity sera giving a titer of approximately 1-1000. In some instances the value was as high as 1-4000. No reaction was obtained when *Aerobacter aerogenes* was mixed with this serum. The titers which we obtained using technique #4 seem to be better than the titers of the sera produced by Bernheimer and Harrison (1, 2) who are the latest workers to publish extensive studies of the serology of *Paramecia*. They used six or seven intraperitoneal injections of whole cells given at weekly intervals.

It is interesting to note that the heated material appears to be non-antigenic if we may judge by the fact that we observed no antibodies following the injections noted above. Reactions were obtained with animals from techniques #1 and #2, but in general the titers of these sera were less satisfactory than that obtained with technique #4. Although the number of animals tested was smaller, reactions obtained with sera produced by technique #5 appear similar to the values obtained by technique #4. In general it would seem that the antigenic material is located on the surface of the paramecia.

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Epidemic Influenza Vaccine and Antiserum

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Preparation of influenza vaccine

Influenza PR8 type A virus was grown 48 hours in the allantoic fluid of eleven-day incubated eggs in the usual way. After the eggs had been chilled in the ice box overnight, the virus-containing allantoic fluid was drawn off with practically no admixture with red blood cells. The virulence of this virus in successive lots averaged 10^{-5} for Swiss mice inoculated intranasally in the usual way.

Each lot of allantoic fluid virus was divided into two portions and treated as follows in the preparation of virus vaccine:

(1) Addition of 'Merthiolate' (Sodium Ethyl Mercuri Thiosalicylate, Lilly) 1:20,000 and incubation one week at 37° C. Three lots of vaccine were prepared in this way.

(2) By a common current method comprising addition of formalin 0.1 per cent plus phenol 0.3 per cent. Three lots of vaccine were prepared in this way.

The vaccine preserved with 'Merthiolate' became nonvirulent for Swiss mice when incubated at 37° C. for one week, and the vaccine preserved with formalin and phenol became non-virulent very quickly without incubation. Continued incubation at 37° C. for four weeks was used as a stability test of the immunizing qualities of these vaccines. During this period of four weeks of incubation of the various lots of vaccine, two active immunization tests were done in Swiss mice. The first test was done after incubation for one week, and the second test was done at the completion of incubation for four weeks. In each immunization test, a group of ten Swiss mice each received 0.1 cc of the vaccine intraperitoneally. This dose was repeated one week later.

One week after injecting the last immunizing doses, decimal dilutions of active virus from 10^{-1} to 10^{-5} were administered intranasally to subdivided groups of both immunized and control mice. The results of these tests are expressed in Table 1 in two ways; first by a fraction, the numerator being the number of mice which died and the denominator being the number of mice used; and second by a total score, dead mice being given a score of 5 while survivors examined at autopsy were given scores of 4, 3, 2, 1, and 0, respectively, corresponding to readings of decreasing lung consolidation. Low scoring immunized mice and high scoring control mice obviously are desirable in immunity tests.

Potency and stability of influenza vaccine

It is observed in Table 1 that influenza virus vaccine treated with 'Merthiolate' shows strong immunizing action, and this is impaired very little by incubation at 37° C. for four weeks. Vaccine treated with formalin and phenol, on the other hand, is impaired greatly in immunizing action by incubation at 37° C. for four weeks.

Influenza type B virus vaccine has been prepared in the same manner as type A with essentially the same laboratory results. A constant difference, however, has been a lower degree of mouse virulence of the B virus.

Pooled types A and B virus vaccines have been tested in mice with results essentially similar to those obtained above. Human tests have not yet been done.

Most of the immunity tests with influenza virus vaccine heretofore reported have given information on activity of the agent at the time of preparation but not necessarily at the time of actual use. Four weeks of heating at 37° C. would not usually occur prior to use; however, variable storage temperatures in transportation and handling prior to use are frequently encountered.

It appears from our stability tests that non-virulent influenza vaccine treated with 'Merthiolate' has a better margin of immunizing effectiveness than non-virulent influenza vaccine treated with formalin and phenol. This conclusion, based on comparative degrees of active immunity obtained against infection with active virus in Swiss mice, obviously means somewhat more than comparative titers of antibodies as measured *in vitro*.

Preparation of influenza antiserum

Rabbit bivalent antiserum against influenza virus types A and B has been prepared for experimental use by methods already described. (1) This serum is of high titer and is intended for prophylactic use by repeated inhalation by intranasal spray whenever epidemic influenza begins to appear in a community. Production of such antiserum is as practicable as production of other antisera, and prophylactic use at the last moment ahead of an epidemic would be both possible and preferable. Reports already published (1) indicate this antiserum when used as described is effective in preventing epidemic influenza types A and B. These types comprise the great majority of all cases of epidemic influenza. There is no evidence thus far that this antiserum is effective in cases which have already developed influenza. In other words, the antiserum, as well as the vaccine, is intended for prophylactic use, but the optimum time of use of each agent would be entirely different. Further details regarding this influenza antiserum are found in the report (1) already referred to.

Summary

1. A stable epidemic influenza vaccine in fluid form has been described. Effectiveness in human subjects has not yet been assayed.

2. Rabbit antiserum against both influenza types A and B viruses has been prepared for prospective inhalation prophylaxis. Effectiveness in human subjects has been indicated by recent publications.

Reference

1. Powell, H. M. Rabbit antiserum against influenza A and B viruses for inhalation prophylaxis against epidemic influenza. J. Ind. State Med. Assoc., 37:18-20 (1944).

Table 1. Tests for immunity incited by type A influenza virus vaccines in Swiss mice.

virus vaccine preparation	dilution of test virus	vaccine incubated 1 week at 37° C.				vaccine incubated 4 weeks at 37° C.			
		vaccinated mice		controls		vaccinated mice		controls	
		dead/used	score	dead/used	score	dead/used	score	dead/used	score
'Merthiolate' treated vaccine	10^{-1}	1/5	8	5/6	28	1/6	10	4/6	27
	10^{-2}	0/6	2	6/6	30	0/6	7	5/6	28
	10^{-3}	0/6	2	6/6	30	0/6	6	5/6	28
	10^{-4}	0/6	2	5/6	28	0/6	2	4/6	23
	10^{-5}	0/6	2	5/6	26	0/5	0	4/6	24
formalin and phenol treated vaccine	10^{-1}	4/6	22	5/6	29	3/3	15(30)*	2/2	10(30)
	10^{-2}	3/6	17	6/6	30	3/4	16(24)	2/2	10(30)
	10^{-3}	1/6	8	6/6	30	1/4	9(13)	2/2	10(30)
	10^{-4}	0/6	4	6/6	30	0/4	1 (1)	2/2	10(30)
	10^{-5}	1/6	6	6/6	28	0/4	0 (0)	1/2	9(27)

* Insufficient mice were available for the full quota of test animals on the second vaccine heated for 4 weeks. Actual scores are indicated, and computed scores, on basis of 6 mice per group, are shown in parentheses.

Application of the Electron Microscope to Biological Research

LUCILE J. WEISS, Lilly Research Laboratories

Research workers dealing with extremely minute particles now have the invaluable assistance of the electron microscope, enabling them to see objects or details not within the resolving power under previous microscopic conditions. In the field of biological research, the possible uses of the electron microscope are almost unlimited. Its application to laboratory problems may be divided into several types, such as routine study of vaccines, or of organisms grown under varying conditions or medicated with different solutions, or research into the realm of smaller bacteria or viruses never clearly observed or seen at all with the light microscope.

In the study of vaccines, the microscope has been used in these laboratories in connection with alum precipitated antigens. It is known that addition of more finely divided particles of alum gives better immunizing results and less reaction. Since this is not too well observed under the light microscope, the electron microscope has been of value in determining relative particle sizes found in various alum precipitated vaccines and in proving the consistency of the particle size in some of the vaccines.

There have been some interesting results of observing more closely the effect of different conditions imposed on the same organism. This has been noted particularly with *Hemophilus pertussis* and *Clostridium tetani*. *H. pertussis* was grown under conditions similar except for the varying use of human plasma and horse plasma in the media. Although there was no difference in the antigenicity of the two groups, there was a significant change in the appearance of the bacteria under the electron microscope. *Cl. tetani* was also grown under similar conditions with only a variation in the type of peptone used in the broth. Here a noticeable change occurred in the antigenicity as well as in the appearance of the organism.

A striking example of the change in medicated bacteria was found in a study of Staphylococcus and Streptococcus grown in inhibiting dilutions of penicillin. Pictures taken by the electron microscope when compared to normal controls showed considerable variation. Staphylococci were greatly enlarged and swelled to the bursting point, while Streptococci also enlarged and showed a tendency to have division inhibited although growth continued. *Cl. welchii* was found to be affected in the same manner.

A very apt subject for study with the electron microscope, and one of interest during the present war in connection with tropical diseases, has proved to be the Rickettsiae of typhus fever. A great deal of variation has been found within the rickettsial cells, which have always been too small to study well with the available resolution of the light microscope. From the small granular type to the larger bacillary form there are many

intermediary forms which might eventually be found to correspond to phases of a supposed cycle. It is hoped that further study might lead to information which will produce a better vaccine.

The only organism studied so far in these laboratories in or allied to the virus group has been that of a pleuropneumonia-like organism taken from the arthritic joints of the rat. Cultures usually appear as gram negative bacilli, but in some instances nothing at all can be seen under the regular light microscope. These latter cultures when observed under the electron microscope revealed very ghost-like forms which have been attributed to the virus form of pleuropneumonia. Some exceedingly bizarre but consistent forms were seen.

The advantages of the electron microscope are rather obvious, and it is easily seen that only a beginning has been made in the vast study of hitherto unknown organisms. It is hoped that some contribution to the fund of knowledge and some betterment to the field of therapy will arise from studies made with this microscope in the future.

History of Bacteriology at Butler University

C. M. PALMER, Butler University

A course in general bacteriology has been offered at Butler University for twenty years. It has been given within the Department of Botany, was first organized and taught by Dr. R. C. Friesner, and since 1926, has been taught by the writer. The course has not been planned for any one particular group of students and almost every year the class has been composed of students with various major interests, such as home economics, chemistry, pre-nursing, botany, zoology and premedical technology. Another large group of students has included those who are interested in work in industrial and government laboratories and who wish to prepare themselves more adequately for such service. This is particularly true of those who have taken the course in the evenings.

The content of the course has, from the first, been rather unusual at Butler University in that it is organized to permit every student to learn to carry out the complete technique in each laboratory exercise, rather than having laboratory assistants hired to run the autoclaves, tend the incubators, prepare the culture media and wash the dishes. This has made it necessary to limit the course to a small number of students at any one time, the maximum now being sixteen. However, those few receive a training which is so complete and thorough that they have an excellent comprehension of the subject and of the special laboratory technique which is a necessary part of the field of study.

From the time the course was first organized, particular stress has been laid on the identification of bacteria, each student being given the problem of attempting to identify to species three "unknowns." This takes the student almost one month and we have found it to be an excellent exercise to give to him, not only an insight into taxonomic bacteriology, but also additional experience in staining, culturing, measuring, checking for spores, testing for physiological characters, etc.

Nine years ago, a course in Applied Microscopy was organized and offered by the writer. It was intended primarily for those students interested in microscopic analysis of tomato products, dairy products, ground foods, fibers, lumber, etc., but it has turned out to be a course to be recommended for all students majoring in botany or microbiology. It includes a considerable amount of microbiology, such as the culturing and identification of molds, the recognition and counting of bacteria in milk and the qualitative and quantitative study of plankton. The morphology and the identification of plankton and of other algae are cared for in the courses in phycology which have been given at Butler University for about fifteen years.

These three fields, bacteriology, microscopy and phycology, constitute the work in microbiology offered at Butler University. The

laboratory manuals for all three courses have been edited and mimeographed at the university. The one for bacteriology is now in its fourth edition.

Students who wish additional training in the field of microbiology have been given specific problems to work on and are required to report in writing the results of their research. Frequently these problems have dealt with the analysis of foods in the condition which they reach the consumer; and such problems, long neglected, have turned out to be very stimulating ones for the students. Some of this research, carried on by graduates, has been published in the Butler University Botanical Studies.

History of Bacteriology at DePauw University

T. G. YUNCKER, DePauw University

In the annual catalogue of DePauw University for 1918-1919 is to be found the following statement: "A special effort has been made during the past year to equip an up-to-date bacteriological laboratory." So far as can be determined, the course which was offered in 1918 was the first ever to be offered in the subject as such at DePauw. It was taught by Dr. Bert E. Quick, now Professor of Biology at Westminster College, who held a temporary appointment in the absence of Dr. Walter N. Hess, who was serving in the armed forces.

The writer became a member of the DePauw faculty in 1919 and inherited the course and the then new equipment which consisted of a small, upright-type autoclave, hot-air oven, electric incubator, Arnold sterilizer, and glassware sufficient for a small number of students. One of the laboratories on the third floor of the old Middle College building had been adapted for the subject by installing a laboratory table with water and gas service and appropriate drawer and locker space for the students.

The course as first taught was designed as a "general introduction with emphasis on the basic principles rather than upon any special phase of the subject" and as such it has continued to the present time. At first the course consisted of two class and two laboratory periods for a credit of four hours, but in 1920 it was changed to a five-hour course by the addition of a third class period. The writer has taught the course continuously since 1919 with the exception of two years while on leave from the university. In 1932-33 it was taught by Dr. Winona H. Welch, of the DePauw faculty, and in 1939-40 by Dr. Ray F. Dawson, now at Princeton University.

For a number of years there was a demand by students for a briefer course in the nature of a survey of the subject. In 1933 such a course was introduced and so arranged that the student might elect it as a two-hour lecture course, or for three hours of credit by including one laboratory period. In 1937 the laboratory was listed as a separate course, thus, enabling students to take the laboratory after having had the lecture work if they wished to do so. At present, therefore, DePauw offers the regular five-hour course in which an attempt is made to be as thorough as the alloted time will permit. In addition to this and the briefer survey course, the student may elect work for three or more hours of credit and carry on problem work along some phase of the subject in which he has developed a special interest.

The number of students electing the five-hour course usually varies from ten to twenty, while the shorter one ordinarily attracts between thirty and fifty. Because DePauw students do not major in the subject, and because of the lack of opportunity to specialize, bacteriologists, as

such, have not been graduated from DePauw. However, some have gone into the field professionally as research workers or teachers. For example, Dr. O. K. Stark, Professor of Bacteriology at Miami University, and Dr. William D. Gray, in charge of the laboratories at Seagrams in Louisville, had their undergraduate work in bacteriology at DePauw.

In the construction of the new Harrison Hall of Science, completed in 1941, more adequate laboratory facilities were provided for bacteriology at DePauw in the way of increased space, an incubator room, modern sterilizing equipment, and other apparatus.

History of Bacteriology at Indiana University*

L. S. McClung, Indiana University

The first course in bacteriology at Indiana University was offered by Professor Robert E. Lyons in the Department of Chemistry one year after his return from a three and one-half-year trip to Europe to study in certain laboratories. During his training in Chemistry (B.A. and M.A. degrees) at Indiana University with Professor Thomas Carleton van Nuys, Professor Lyons had developed an interest in the branch of chemistry we now call biochemistry and in zymochemistry or the chemistry of fermentations. To further his education in these matters he went to Germany in the fall of 1892 and studied bacteriology at the University of Heidelberg and in the laboratory of Professor Fresenius at Biesbaden. Later he also studied at Jorgensen's laboratory in Copenhagen and with Metchinkoff at the Institute of Pasteur in Paris.

The first course which ran throughout the year, was given as an elective course in the evenings from six to nine on the Monday, Wednesday and Friday evenings. The students primarily were advanced and graduate students in chemistry. For the work in bacteriology there were available several rooms including a laboratory, an office and an adjoining media kitchen on the second floor in the north end of Wylie Hall. The laboratory was equipped with work tables facing the windows around three sides of the room, and general work and preparation tables were placed in the center of the laboratory. The work tables were covered with alternate squares of black and white enameled plate glass, and which, according to the catalogue, made possible absolute cleanliness and furnished a choice background in the observation of cultures! The professor's office occupied a small corner of the wing and opened directly into the laboratory. The kitchen adjoined the laboratory on the side of the central wing of the building.

The laboratory equipment was good for its time. Certain of the larger items had been purchased by Professor Lyons in Germany, as President Swain had made available certain funds for this purpose in order that the most modern equipment be viewed and purchased. The sterilizers consisted of a hot-air oven and, from Berlin, a Koch intermittent steam sterilizer (gas heated). Since Petri plates were then unknown, the plating was done on plain glass plates which had been sterilized in a tight metal container. Very little agar was used as a solidification agent, so gelatin was poured on the glass plates which were

* The author is greatly indebted to Professor Robert E. Lyons for contributing much of the information upon which this report was based. In addition to this Professor L. F. Rettger, of Yale University, kindly prepared a short summary of the material relating to the years when he was a student, and likewise, Professor I. M. Lewis, of the University of Texas, supplied certain facts shortly before his death.

cooled on blocks of ice and placed on small glass benches under a bell jar. Thus plating was an arduous task especially if the gelatin had been overheated and failed to solidify but ran down the sides of the glass. Cultures which liquefied the gelatin gave rise to more trouble.

There were twelve Bausch and Lomb microscopes, each equipped with ⅓, ⅙ and ½ objectives, as well as a modern microtome. Anaerobic cultures were prepared by the hydrogen displacement method, involving the well-known expedient of testing the degree of oxygen displacement by the test tube Bunsen flame test. Considerable excitement was caused one evening when three or four students were using this procedure. The most daring in the lot insisted on standing over the gas-displacement jar when making the combustion test. He started to collect a second sample of gas from the bell jar, when suddenly there was a loud report and the upper part of the bell jar was hurled to the ceiling by the force of the explosion, the jar just grazing the nose of the daring experimenter. The hole in the ceiling made by the knob of the bell jar long remained as a grim reminder of what questionable judgment and technique might bring to future "experimenters." Thus we have the picture of the laboratory.

Two courses were offered in 1896-97—Chemistry 16 and 17. The former was the lecture course and was described officially as follows: "Lectures and demonstrations concerning the structure and composition of the bacterial cell; the life history and environment of bacteria; the germ theory of disease; the chemical nature of the products of bacterial activity; the technical application of bacteriology." Chemistry 17 was the parallel laboratory course and of it we have "Methods of culture; isolation and identification of the common non-pathogenic and pathogenic microorganisms; inoculation experiments; staining of sections; bacteriology of water, etc." In 1897-98, Chemistry 25 or "Special independent work" was added to the list. By 1901-02 the demand was such that additional laboratory sections introductory courses were arranged and the lecture course moved to the day time hours—Monday, Wednesday and Friday at 2:00. About this time course 25 became a series of lectures on selected topics including disinfection, immunity, serum therapy, filtration of water, etc. Course 26 was added. This was a laboratory course concerned with the following: Bacteriological examination of air, water, and foodstuffs, testing of disinfectants, antiseptics, and sanitary appliances. A reading knowledge of German was prerequisite in addition to the elementary bacteriology courses. The final course added, about 1902, was "Bacteriological Chemistry" and this was concerned with laboratory work in the preparation of metabolic products of microorganisms and the testing of antitoxins. In addition to German and elementary bacteriology the prerequisites included organic chemistry and physics.

For some years, about 1900, instruction during the summer was offered, first at the Indiana University biological station at Turkey Lake and later at Winona Lake, and at the same time opportunity was afforded for the study of lake flora. Early assistants in bacteriology included Leo F. Rettger, Frederick N. Duncan, and George F. Bicknell.

In the fall of 1903, in recognition of the modern trends in medical education, Indiana University established as a separate division a medical school. Two years of collegiate work were required for entrance and only the first two years of the medical work were offered. All instruction was on the Bloomington campus. Included in the winter and spring terms of the curriculum of the second year were the introductory courses in bacteriology (Chemistry 16a and 16b), which were given by Professor Lyons, who gave, also, the courses in organic chemistry and physiological and pathological chemistry. In 1905 the Department of Pathology was established. The instructional work in bacteriology was transferred to the department with Wilfred H. Manwaring, Associate Professor, giving the lectures in the first years. The laboratories in Wylie Hall were continued and a small animal barn was available for the production and study of curative sera.

By 1907 he was aided by Lemuel W. Famulener as assistant professor. About this time the work of the second year was concentrated on the Indianapolis campus and thus the Bloomington campus was left without instruction in bacteriology. Professor Manwaring resigned and was succeeded by Henry R. Alburger, who was aided in the early years by T. V. Keen, Harry K. Langdon, Cameron Chamberlain, J. P. Christie, Alfred Henry, Walter F. Kelly, John D. Stewart and Ada Sweitzer.

Of considerable importance with reference to the training offered by Professor Lyons in the early days is a list of several students who were destined to become prominent in the field of bacteriology and related sciences. Leo F. Rettger, who served as a graduate assistant, was one of the first to take the M.A. degree in biochemistry and leave the school for additional study at Yale University. It was not long before he was well known as Professor of Bacteriology at Yale. James N. Currie, after working for the Bureau of Agriculture in Washington, became associated with the Charles Pfizer Company in Brooklyn. There he developed an outstanding commercial process for the production of citric acid by mold cultures. Willis D. Gatch is now Dean of Indiana University School of Medicine. The name of George Dick is known to all of you in connection with the Dick Test. Oscar Schultz later became Professor of Pathology and Bacteriology at Western Reserve University. Isaac M. Lewis, a student of Manwaring, became Professor in charge of Bacteriology at the University of Texas.

The following notes relative to bacteriology at WABASH COLLEGE were received in a letter from Professor A. R. Bechtel, who was unable to be present. Bacteriology was first offered at Wabash College in 1893-94 by Professor Mason B. Thomas, who came from Cornell University. The course was offered primarily for science majors and pre-medical students. Essentially the same material is offered at the present as a four-credit course.

History of Bacteriology at the University of Notre Dame

ROBERT F. ERVIN, PHILIP C. TREXLER, and JAMES A. REYNIERS,
University of Notre Dame

Bacteriology has been taught at Notre Dame for approximately 55 years (1, 2). The course was first listed in the University catalogue in 1890 but the late Dr. John Berteling, one of the earliest students and a member of the faculty at the time, claimed that he taught bacteriology in 1888 (3). The authors were not able to find this record, but other courses in biology were taught much earlier than 1890 (1, 2, 4, 5). Early catalogues did not state the teacher of the subject but it is presumed that Rev. Alexander M. Kirsch, C.S.C., taught bacteriology in 1890 since he was a teacher of natural science during that period (6). Dr. Berteling claimed to have taught Father Kirsch bacteriology and this is quite possible, although Father Kirsch was an older man and had had two years of graduate study in cytology at Louvain. Moreover, the late Dr. Francis J. Wenninger, C.S.C., who was a pupil of Kirsch and knew him well, said that Kirsch had visited Koch's laboratory while in Europe (7).

Kirsch was not primarily a bacteriologist but rather a zoologist and it is interesting to note that for over forty years at Notre Dame, bacteriology was not taught by anyone whose primary interest was in bacteriology. Curiously enough, Notre Dame had a bacteriologist on its faculty before 1900 but he occupied a chair of literature. This man, Dr. Austin O'Malley, had served as bacteriologist for the Marine Hospital in Washington, taught bacteriology at Georgetown Medical School, and was recognized by no less an authority than Osler of Johns Hopkins for his work in introducing diphtheria antiserum to the American medical profession (8). Dr. O'Malley did not teach bacteriology at Notre Dame but he did influence Father Kirsch's thinking on the subject.

The early course, according to catalogue description, was a general one emphasizing non-pathogenic bacteria and the methods for studying them. The description was about the same as one would find today for any modern course in general bacteriology.

The course remained unchanged until 1916 at which time a second course in bacteriology was introduced which laid special stress on infection and immunity to bacteria and the specific infectious diseases (9). During the early period there is little record of who taught bacteriology except for a period of 1905 to 1908 when Rev. Leo. A. Heiser, C.S.C., taught it (10). The subject was probably taught at various times by Dr. Francis Powers, Father Kirsch, Father Wenninger, Rev. Frank O'Hara, C.S.C., and Dr. Regidius M. Kaczmarek. In 1919 a course in immunity was introduced and taught by Kaczmarek. He continued to teach this course until 1924 (11).

Dr. George Albertson, C.S.C., trained in zoology, took over bacteriology and immunology in 1923 (12). This man was to devote his entire time to teaching these courses together with hygiene. He taught bacteriology to one of the authors, Reyniers, in 1928. He was a kindly man, a good teacher and had some knowledge of research. Above all, however, Father Albertson inspired the research efforts of those working under him and constantly served as stimulus for original and basic work.

After the death of Father Albertson in 1929, Father Wenninger, then Dean of Science and Head of Biology, recalled James A. Reyniers in 1931 to teach bacteriology and to continue with the research projects which he had begun as an undergraduate in 1928. Reyniers has taught all of the courses in bacteriology and immunology and several courses in hygiene since 1932 (13).

With the encouragement of Dean Wenninger and others, Reyniers established and started work upon a long range program toward the eventual investigation of some of the fundamental problems concerned with the biology of microörganisms. Except in the field of physiology, few contributions have been made to experimental biology from the study of bacteria. This has obviously been due to the limitations set by the minute size of the bacteria. With this in mind, the first phase of the program was devoted to perfecting those techniques which seemed most likely to circumvent difficulties connected with size. Three techniques seemed to offer promise. They were: the elimination of contamination in order to keep cultures pure under all conditions, micrurgy for working with individual organisms, and mechanization of the viable count for handling large numbers of living units.

When this work was begun, there was one teaching laboratory, a small incubator room, and a small room for sterilization. In these quarters and with meager equipment, Reyniers began to develop the basic micrurgical and germ-free techniques. As the work continued and showed promise, the University administration supplied another room and appropriated a small fund for some badly needed apparatus. In 1932, an undergraduate, Philip C. Trexler, began to work with Reyniers as an assistant in the laboratories. After receiving his M.S. degree in 1936, Trexler became associated with Reyniers and the work on a full time basis, although between 1936 and 1940, he was given several leaves of absence for study at other universities and institutes.

During these years of the early 1930's, the academic program in bacteriology had expanded to include several courses in hygiene and some advanced courses in research and techniques. Graduate assistantships were granted to one or two promising students per year and these men worked two and one-half years toward their Masters degrees on the apprenticeship basis. These men assisted in teaching laboratory courses and also assisted with the research program which by this time had begun to attract wide attention. The administrative officers of the University especially President Charles L. O'Donnel, C.S.C., Vice-President John F. O'Hara, C.S.C., and Dean Wenninger, had become much interested in and sympathetic toward the research. They made available

more and more facilities and funds. With the exception, however, of Trexler, Reyniers was not supplied with technically trained help.

In 1933 Reyniers was made Head of the Laboratories of Bacteriology, to be devoted to research. In 1937 he became Director of the Laboratories.

By 1936 the program had expanded in size and scope and was now occupying five laboratories and an office in the old Science Hall. At this time, Father John O'Hara was President of the University and under his direction and leadership, plans were made for a new Biology Building, one floor of which was to house the Laboratories of Bacteriology. Work was begun in the summer of 1936 and the building was dedicated in the spring of 1937. At this time, the junior author of this paper received his B.S. degree in Pharmacy and began work toward an M.S. degree under Reyniers and Trexler. These three men, Reyniers, Trexler, and Ervin have, since that time, administered the research and teaching of the Laboratories of Bacteriology.

The much more adequate quarters in the new building provided some twenty-two laboratories and offices primarily devoted to research. Included among these are special rooms for the animal colony, for the experiments in micrurgy, for the study of cross infection, and for the germ-free experiments. In addition to the three men named above the staff is now made up of six full time research technicians, three assistant technicians, a stock room attendant, an animal keeper and a machinist.

With this staff, the first phase of the research program, i.e., the laying of a sound foundation of principles, techniques, and apparatus, has been practically completed. This has been made possible by working the year around and by devoting many hours in addition to the ordinary academic program. Apparatus has been built in which it is possible to perform almost any bacteriological experiment including animal inoculation, without danger of contamination. In this same apparatus guinea pigs, rats, chickens, rabbits, dogs, flies, fish, plants and monkeys have been raised free from detectable contamination. Limitations in the field of animal nutrition have caused considerable deviation from the main problem in theoretical bacteriology. These animals have been used in a variety of problems such as the problem of dental caries in cooperation with the Zoller Dental Clinic of the University of Chicago. From time to time circumstances have made it necessary to make immediate application of the technique. As an example, units of cubicles have been designed for the elimination of cross infection in hospital wards. Cubicles of this type have been installed and used in the Cradle in Evanston, Illinois, for four and a half years.

Micrurgy developed along many lines, one of which resulted in a method of single cell isolation. This was not much more involved than the standard plate method for obtaining pure cultures.

Preliminary studies of the mechanization of the viable count were made in 1932. Since then, circuits, as yet unpublished, similar to those used in counting the discharges of Geiger-Mueller tubes have been developed. With these circuits plates having over a thousand colonies

may be counted in less than a minute with an accuracy not approachable by the human eye in routine work.

The first formal presentation of these techniques and their use was made at a Colloquium on Micrurgy and Germ-Free Techniques held at the University of Notre Dame in 1939. At this meeting papers were read which summarized the instrumentation and use of the germ-free, micrurgical and cubicle techniques. These papers along with those of other men working in related fields have since been published in book form.[1]

In normal times academic program in bacteriology at Notre Dame offers the following courses; Biology of Bacteria, Bacteriology for Engineers, Elements of Immunity, Epidemiology, Elementary Hygiene, and Personal and Community Hygiene.

The research program is being carried on with the generous support and encouragement of the present University administration headed by the Reverend J. Hugh O'Donnell, C.S.C., President. The advent of war has demanded that all long range research programs be curtailed in favor of immediate applications. It is hoped, however, that these techniques may be applied to the advancement of the pure science of micrology after the war.

Acknowledgment

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History of Bacteriology at Purdue University

P. A. TETRAULT, Purdue University

The development of Bacteriology at Purdue University has followed the general pattern set by Pasteur and Koch. The diseases of animals were first considered. We find in the University catalog for the year 1893, a course offered in Veterinary Science by Professor A. W. Bitting in which the diseases of animals due to bacterial infections were considered. It would be assumed that this consideration was very incidental, as the description of the course stresses at great length the question of surgery and pathology.

In 1894 the following outline is given in the catalog: "Bacteriology.—Twelve Weeks. The general morphology and classification of the bacteria, their development and most important biological relations are studied. The laboratory work includes the general methods of research, and also such special forms of investigation, i.e., the biological analysis of water, etc., as members of the class may desire. Professor Arthur."

Dr. J. C. Arthur was Professor of Botany and later acquired international fame in the field of Mycology. He was an authority on rusts and his books on the subject are still the classical references.

In 1895 there were two courses described that belong to the general field of Bacteriology: "Biology 6: Fermentation. Twenty-three weeks, eight hours per week. Preliminary study of yeasts, moulds and bacteria leading to the morphological and physiological study of organisms found in bread, beer, cider, moulding fruits, milk, prepared foods on the market, etc. The work is of a practical nature, and is designed to give a student a working knowledge of the problems affecting foods. Jorgensen's Micro-organisms of Fermentation is used in connection with other standard works, as text. Instructor Golden."

Miss Katherine Golden later married Dr. A. W. Bitting, who became Food Technologist in the Bureau of Chemistry, U. S. Department of Agriculture and later was connected with the National Canners Association, leaving this concern to become a consulting Food Technologist. No doubt Mrs. Bitting had no small part to play in these various endeavors. Dr. Bitting has since retired and lives in Lafayette, Indiana.

In that same year, 1895, we find another entry in the catalog entitled Biology 11. "Bacteriology: Thirty-seven weeks, eight hours per week. A general course, utilizing the modern methods of culture for the study of bacteria, and bearing particularly upon the bacteriological examination of water, sewage, ice, air, soil, milk, butter, etc., and the application of such results in the solution of modern sanitary problems. The members of the class make reports once a week on current articles bearing on this subject that appear in scientific periodicals. Instructor Burrage."

When Dean Stanley Coulter found that this new development in biology required special training that was not offered in courses in

Botany, he asked Dr. Severance Burrage, a recent graduate of Massachusetts Institute of Technology, to join the biological staff. His training was primarily along Public Health lines and the description of the course bears this out. From Purdue, Dr. Burrage went to Eli Lilly and then to the University of Colorado. He has since retired.

It is interesting to note that whereas Bacteriology was taught by botanists at the beginning we now see the process reversed. Dr. Burrage taught two courses in Botany as well as six courses in Bacteriology before his Purdue career ended. He taught students majoring in Agriculture, Biology, Household Economy and Civil Engineering.

From this meagre beginning, bacteriology developed at Purdue University as the need arose. In the Department of Veterinary Science, where its applications could be most readily used, there were two bacteriologists employed following the resignation of Dr. A. W. Bitting. Dr. R. A. Craig, a graduate of Iowa State College, came to Purdue in 1899 as Head of the Department. His specialty was diseases of swine, particularly hog cholera; a knowledge of bacteriology was essential for his work. He died in 1939.

It was Dr. Craig who was responsible for bringing Dr. R. A. Whiting to Purdue as bacteriologist and pathologist in the Veterinary Department. Dr. Whiting did no teaching but was very busy doing experimental work and directing undergraduate students in their research for their theses which were then required of all students.

In 1912 the Dairy Department felt the need of bacteriology to further their work with milk and its various products. H. B. Switzer, a recent Cornell graduate, developed the beginning courses in Dairy Bacteriology. He was Assistant Professor from 1915 to 1917 at which time he left Purdue University to become associated with the U. S. Department of Agriculture. At the present time he is in charge of the Inspection of Food Plants carrying Good Housekeeping seals of approval.

Professor Switzer was followed by H. M. Weeter, who remained at Purdue only one year. He taught General Dairy Bacteriology and went to the University of Louisville from here.

From 1917 to 1921 there were no bacteriologists connected with the Dairy Department. In 1921, E. H. Parfitt came to Purdue from the U. S. Department of Agriculture. He obtained his Ph.D. degree from Iowa State College in 1934, returning to Purdue where he remained until 1940. He is now connected with the Evaporated Milk Association.

There were three graduate students in the Dairy Department during Dr. Parfitt's tenure. Leonard R. Dowd, a Michigan State College graduate and M. S. Purdue University, 1932, replaced Dr. Parfitt in 1932-1933 during the latter's leave of absence. He went to Connecticut State College, where he is connected with the Dairy Department.

F. J. Babel did some graduate work at Purdue University in 1935-1936, leaving to become Research Associate in the Dairy Department at Iowa State College. He was followed by W. H. Brown in 1936, who remained here until 1943. Mr. Brown is now doing control work with the City Board of Health of Jacksonville, Florida.

Dr. P. R. Elliker of the University of Wisconsin filled the vacancy created by the resignation of Dr. Parfitt.

The Horticultural Department employed a bacteriologist for a few years. H. A. Noyes, a graduate of Massachusetts College of Agriculture, came to Purdue in 1913 and was Research Associate in the Agricultural Experiment Station until 1917, when he left Purdue to engage in bacteriological research work with the Welch Grape Juice Company.

The Department of Botany in the Agricultural Experiment Station has a soil bacteriologist as a member of its staff. Dr. J. L. Roberts from Wisconsin, was made associate in 1937.

In 1912, the vacancy created by the resignation of Dr. Burrage was filled by Professor C. M. Hilliard. Like Dr. Burrage, Professor Hilliard was trained at the Massachusetts Institute of Technology and was primarily interested in Public Health. He resigned in 1914 to become head of the Department of Public Health at Simmons College in Boston, which position he still holds.

During the tenure of Professor Hilliard, the first assistant in Bacteriology, T. J. Murray, a graduate of the College of the City of New York, 1913, was employed. He obtained his M.S. degree in 1915 and accepted a position as Associate Professor at Virginia Polytechnic Institute. He is now Professor of Bacteriology at Rutgers.

Dr. C. A. Behrens replaced Professor Hilliard in 1914, coming to Purdue from Michigan, where his training was obtained under the direction of Dr. F. G. Novy. He was well grounded in the fundamentals of Bacteriology and we find a transition taking place at Purdue dating from this time. Public Health was gradually replaced by the more exact science, Bacteriology. The equipment at this time was not extensive for the kind of work that Dr. Behrens wished to carry on, and we find him struggling along for the first two or three years with very little. The courses in Public Health were gradually replaced by courses in Pathogenic organisms, Serology and Immunology and Technique.

At the present time besides Dr. Behrens, there are two professors and one instructor in the division of bacteriology. P. A. Tetrault came to Purdue from Clark University in 1912 as assistant in General Biology. In 1917 he was advanced to Assistant Professor of Bacteriology and taught in the general field until 1923, when he went to the Pasteur Institute for a year's study with Professor August Fernbach along fermentation lines. Wisconsin granted him the Ph.D. degree in 1929. He developed the field of fermentation at Purdue.

S. E. Hartsell, a Michigan State graduate, was made a member of the Purdue staff in 1936. His M.S. and Ph.D. degrees were obtained at Yale University under the direction of Dr. Leo F. Rettger. Before coming to Purdue he taught at Battle Creek College and was in the Agricultural Experiment Station at Connecticut State College. He has developed the work in Food Bacteriology and is interested in the immunology of poultry.

J. M. Rush now holds the position of Instructor in Bacteriology. He is a graduate of Indiana University, 1928, and completed his work for the M.S. degree at Illinois in 1935.

As any historical review is a record of the achievements of the various members of the organization, a brief summary of the accomplishments of the assistants who have gone through the department and the members of the staff who have come and gone will not be out of place. The list is a rather long one and only a short sketch of each can be included.

Many of the assistants went on to schools of medicine after obtaining their M.S. degrees. In that list we find R. B. Robertson, (M.S. 1924), D. W. Creel, (M.S. 1926), R. E. Carmen, (M.S. 1927), L. J. Holliday, (M.S. 1928) and Miriam Smith, (M.S. 1930). All of these were Purdue graduates and are now practicing physicians. M. A. Jacobson came to Purdue from West Virginia and after obtaining his M.S. degree in 1918 went to Chicago Medical where he was granted both Ph.D. and M.D. degrees. He is a colonel in the U. S. Army.

George Stuppy spent the years 1921-1922 in the Department of Bacteriology after obtaining his bachelor's and master's degrees from Purdue. He went to Chicago and obtained both the Ph.D. and M.D. degrees from that institution. After three years teaching at Texas A. and M. as bacteriologist, he returned to the University of Chicago as instructor in Hygiene and Bacteriology. He is now practicing medicine.

Russell Greenwood obtained his M.S. degree in 1930 after completing his undergraduate work here. After two years as an instructor in Bacteriology he went to the Univeristy of Pennsylvania Medical School, where he was granted the M.D. degree. Upon graduation he went to Rutgers College as half-time Professor in Bacteriology and half-time in the Student Health Service.

W. E. Scheunemann and J. F. Brown, both recent recipients of the M.S. degree, the former from Wisconsin and the latter from Arkansas, are at present attending medical school.

Two of the assistants with M.S. degrees from Purdue have become hospital technicians. C. E. Heaton, a Purdue graduate of 1928 and M.S. 1930, is now located at the Hackensack hospital in New Jersey. F. L. Willis, graduate of Indiana State College in 1929, became technician for the Student Health Service after getting his M.S. degree and serving three years as instructor. He is now a captain in the Sanitary Corps.

In the field of Pharmacy we find two former assistants. L. B. Morgan came to Purdue from Oregon State College in 1930 and obtained his M.S. degree in 1931. He went back to the state of Oregon and is now conducting his own business. J. A. Shrader, a graduate in Pharmacy at Purdue in 1930, was granted his M.S. degree in 1932 and went into the pharmacy business in the southern part of the state. He is now with the Department of Public Health of Kentucky at Lexington.

G. D. Kennedy, a Purdue graduate, went into pharmaceutical work after two years assistantship.

In the teaching field there are several Purdue assistants who have made their mark. I. L. Baldwin, a Purdue graduate of 1918, came back to Purdue as assistant in Bacteriology after serving a year in the Army. He obtained his M.S. degree in 1921, was retained as instructor and was later promoted to Assistant Professor. He developed the courses in Soil

Bacteriology. In 1925 he went to Wisconsin, where he was granted the degree of Doctor of Philosophy in 1927, returning to Purdue as bacteriologist in the Agricultural Experiment Station and from there was called back to Wisconsin, where he has held the positions of Professor of Bacteriology, Assistant Dean of the School of Agriculture, and now Head of the Division of Agricultural Bacteriology. He was secretary of the Society of American Bacteriologists for many years, its vice president for one year, and is now its president.

A. W. Tallman, a 1928 Purdue graduate, was granted the degree of Master of Science in 1930 and then left to fill a position with the Michigan State Board of Health. From there he went into the field of biologicals and is now located at Western Reserve in the teaching field.

H. F. Marsh obtained his M.S. degree in 1931, coming to Purdue from Indiana State College. For a few years after leaving here he was connected with a Biological firm in Cincinnati and from there went to Ohio State University, where he was granted the degree of Doctor of Philosophy. He is teaching Bacteriology at Oklahoma.

L. B. Schweiger, a Purdue graduate, assisted in Bacteriology in 1936 and 1937. After getting his Master's degree he went to Arkansas where he taught Bacteriology in the School of Agriculture. He has completed the preliminary requirements for the Ph.D. degree at Purdue and will be a candidate for the degree when he returns from the Sanitary Corps.

G. C. Wickwire, a 1920 Purdue graduate, obtained his M.S. degree in 1922 and went to Illinois, where he is teaching Physiology.

The fermentation field has absorbed a long list of our graduates. C. H. Keipper, who graduated from Purdue and assisted in Bacteriology in 1926 and 1927, accepted a fellowship at Wisconsin after receiving his M.S. at Purdue. He was granted the Ph.D. degree in 1930 and left to become head of production at the Red Star Yeast Company in Milwaukee.

W. L. Weis, Purdue 1929 and M.S. 1932, went to Hiram Walker and Sons, Inc. and is now with the Schenley distilleries at Lawrenceburg. J. F. Barker, Purdue 1933 and M.S. 1935, went to The Terre Haute Brewing Corporation. G. E. Hines, Purdue 1936 and M.S. 1938, was employed by Lederle Laboratories, Inc., and later by Commercial Solvents Corporation at Terre Haute, where he is now located and heading the research on Penicillin.

H. C. Murray, Purdue 1937 and M.S. 1939, stayed at Purdue to complete his work for the Ph.D. degree. He was granted that degree in 1941 and was called to The Upjohn Company to work in the research department. His work on Penicillin was of such a nature that he was made head of production for Penicillin. He is assisted in this work by S. M. Morrison (B.S. Massachusetts State, 1941; M.S. Purdue, 1942).

H. Piersma left Lederle Laboratories, Inc., in 1935 to become instructor in Bacteriology at Purdue. He was granted the degree of Doctor of Philosophy in 1939 and returned to Lederle Laboratories Inc. After three years with this firm he resigned to go to The Upjohn Company in their research department.

M. T. Walton, B.S. 1932 and M.S. 1933, is now head of production at the Peoria plant of Commercial Solvents.

In the field of biologicals we have W. W. Ferguson, Purdue 1929 and M.S. 1931, with the Michigan State Board of Health; G. H. Echelbarger, Purdue 1936 and M.S. 1938 with Pitman Moore and Company; J. O. MacFarlane, Purdue 1940 and M.S. 1942, with Squibb and Company; M. C. Creditor, Purdue 1940, with Lederle Laboratories Inc. A. E. Bolyn, M.S. Lehigh 1938, worked towards his Ph.D. degree until 1941 and then went to Pitman Moore and Company and then to National Drug Company. E. Voigt, the second assistant in the Department of Bacteriology at Purdue, was a Purdue graduate in 1915. He went to Lederle Laboratories Inc. after two years of graduate work and is head of production.

H. C. Travelbee, M.S. Purdue 1916, C. D. Goodale, M.S. 1924, Don Cook, M.S. 1935 and N. R. Tarvin, M.S. 1932, all Purdue graduates, have gone into the business field as salesmen.

R. K. Jennings and R. L. Phillips, B.S. 1933 and M.S. 1935, are located at the Franklin Institute for Cancer Research.

George Kensler, B.S. 1928, left Lederle Laboratories Inc. to get an advanced degree at Purdue. He was granted the Ph.D. degree in 1938, and went to Kraft Cheese Company, where he is chief bacteriologist.

There are two men who were on the Purdue staff but who had to leave because of the war situation. G. D. Canatsay graduated from Purdue in 1937 and obtained his M.S. in 1939. He was an instructor when he left in 1942 to join the Sanitary Corps. Dean R. Bahler, B.S. 1939 and M.S. 1941, left in 1942 before completing his work. He is an ensign in the U. S. Navy.

Within recent years work along the lines of clinical diagnosis has been developed at Purdue. Dr. L. J. Arbogast, until his induction into the Army Medical Corps and Miss Marie Martin, B.S. Purdue 1931 and M.S. 1934, both from the Home Hospital in Lafayette, carry on the work in this field.

There have been several who have obtained their undergraduate training at Purdue and who have gone on in the field of bacteriology. We like to believe that their inspiration was gathered here. I have in mind such men as C. H. Werkman of Iowa State College. He graduated from Purdue in 1919 and is now one of the leading international figures in the fermentation field.

From a very small beginning of one instructor teaching one-half semester of bacteriology in 1893 there are now on the Purdue University campus two full professors, one associate professor, one assistant professor, one instructor and five assistants, all teaching bacteriology. In addition to this there is one associate in the Agricultural Experiment Station who devotes all of his time to research in Bacteriology.

BOTANY

Chairman: A. T. Guard, Purdue University

Professor Benjamin H. Smith, Indiana State Teachers College, was elected chairman of the section for 1944.

The morphology of the Paleozoic fructification Bowmanites (Sphenophyllales). A. T. Cross, University of Notre Dame.—The new species of Bowmanites, *B. trisporangiates* Hoskins and Cross, from an Iowa coal ball has made possible a revision of the generic concepts of this long known group of plants. The gross morphology and general anatomy are reviewed. An attempt is made to analyze the nature and origin of the sporangiophore as a unit of structure in this cone genus and to relate it to allied forms. A new interpretation of the spore walls is possible and the presence of a perisporium associates this group of plants more closely with the Sphenopsida.

Correlation of microclimatic factors with species distribution in Shenk's woods, Howard County, Indiana. Ray C. Friesner, Butler University, and Charles M. Ek, Kokomo.—Shenk's woods, a large tract of primeval forest, six miles east of Kokomo, very obviously to the eye, comprises two types of forest. About one-fifth of the total area is very sharply set off from the remainder by differences in its component species. The larger portion may be characterized as Quercus-Ulmus in which four species of oak (*Q. borealis* var. *maxima*, *Q. bicolor*, *Q. macrocarpa*, and *Q. muhlenbergii*) occupy 56.3% of the crown cover; *Ulmus americana*, 20.4%; *Fraxinus americana*, 6%; *Acer saccharum*, 4.95% and *Ulmus fulva*, 4.43%. In the smaller area, *Acer saccharum* occupies 66.1% of the crown cover, Quercus spp., 19.1%; *Fagus grandifolia*, 11.1% and *Ulmus fulva* 5.95%. The herbaceous species are strikingly different in the two areas. The Quercus-Ulmus area shows very few spring-flowering species and these in low frequencies while the Acer-Fagus area shows both a larger number of the early-flowering species and all of them in high frequencies. Summer- and Autumn-flowering species are also much fewer in number and of lower frequencies in the Quercus-Ulmus area than in the Acer-Fagus area.

Evaporation studies show very similar rates in the two areas, the curves completely paralleling each other with first one and then the other a little higher.

Study of edaphic factors shows that the moisture equivalent is higher in all horizons in the Quercus-Ulmus than in the Acer-Fagus area. In spite of the higher moisture equivalent the percentage of growth water in the soils is higher at all horizons in the Quercus-Ulmus area and the differences are much accentuated during the critical weeks of

July and August. Differences in the species occurring in the two areas is probably largely due to the differences in composition of the soil which in turn affects soil temperature, aeration and available growth water.

A chronological chart for plant physiology. RAYMOND E. GIRTON, Purdue University.—A chart has been devised which presents parallel developments in nine sub-divisions of plant physiology and in world events. The physiological sub-divisions considered are: (1) general, (2) the cell, (3) photosynthesis, (4) nitrogen metabolism, (5) mineral nutrition, (6) water relations, (7) translocation, (8) respiration, and (9) growth. Progress in each sub-division is connected with the names of individual authors and is arranged in chronological order.

The effects of different sources of nitrogen on the deficiencies of certain mineral elements in tomato plants. WENDELL R. MULLISON and DOROTHY L. SCOTT, Purdue University.—This is a progress report on the effect of two types of nitrogen compounds on the deficiency signs and symptoms of several nutritional elements. The types of nitrogen were an oxidized form such as nitrogen in a nitrate salt and a reduced form of nitrogen such as the nitrogen present in urea. The compounds used were calcium nitrate, urea, ammonia, guanidine nitrate, and guanidine sulphate. Calcium nitrate produced the most favorable growth and urea seemed to be the best of these compounds containing nitrogen in the reduced form. The mineral deficiencies involved were for calcium, potassium, phosphorus, magnesium, sulphur, manganese, and boron respectively.

The deficiency symptoms of plants supplied with urea as contrasted with those plants supplied with nitrate nitrogen were different in several cases. Although the plants grown on nitrate nitrogen in general were better than those plants supplied with urea nitrogen, in some cases the onset of the deficiency symptoms was delayed when urea was used as a nitrogen source.

A card game designed as an aid in teaching the characteristics of gilled mushrooms. C. L. PORTER, Purdue University.—Two sets of cards are used. Set I, known as the "genus set," has the name of a mushroom genus printed on each card. Together with the name of the genus there is also typed below the name the three to six characteristics that are necessary to differentiate that particular genus from all other genera.

Set II, known as the "characteristic set," has one distinguishing characteristic printed on each card.

Genus cards are distributed equally among the players. Five "characteristic" cards are dealt to each player. The remaining "characteristic" cards are stacked in the center of the table.

The object of the game is for each player to acquire a group of characteristics that will define definitely a mushroom genus. When he has succeeded in doing this he has a "book." Books differ in value depending upon the number of characteristics that must be assembled to define a mushroom genus. A three-"characteristic" book has a value of three points; a four-"characteristic" book has a value of four points, etc.

The player with the most points at the end of the game wins.

This game was used as a part of classroom exercises with extraordinarily good results. Not only did class members learn very rapidly the characteristics of the mushroom genera but they aided greatly en field identification.

It is the opinion of the author that such a device could be used in teaching the basic principles underlying the classification and identification of many groups of organisms.

Pollen-grain structure in the classification of Spermatophytes. DOROTHY L. SCOTT, Purdue University.—The external characters of pollen grains were studied in order to determine their value in establishing phylogenetic positions of plant groups. Such pollen-grain structures as size, shape, furrow configuration, and external markings exemplify trends of development paralleling Bessey's system of plant classification. As unit characters, these pollen-grain structures are not indicative of relationships of orders within a phyletic line or of families grouped in an order. A high degree of similarity of characters of pollen grains from genera within a family suggests that the family may be used as the unit of pollen-grain structure. There are relatively few plant families that cannot be distinguished by their pollen grains. Differentiation of species is seldom shown by external pollen-grain structures.

The Development of the Seed of Liriodendron Tulipifera L.

A. T. GUARD, Purdue University

Considering the great number of hazards which a young tree must overcome before it is established, it is important that a forest species produce a considerable number of viable seed. It is also highly desirable in reforesting that an abundance of good seed can be gathered with a minimum of time and labor. This is especially true where direct seeding is practiced.

The common tulip tree *Liriodendron tulipifera L.* is one of our most desirable eastern hard wood species both because of its size and the quality of the wood which it produces. This species characteristically produces many well-developed fruits. Very few of these fruits have well-developed seed in them.

The purpose of this, and previous studies on this problem has been to see what the cause or causes might be for the failure of many seeds to develop properly. With this in mind the course of the development of the seed has been followed from the time of flowering until maturity.

Shortly after pollination the development of the integuments and nucellus is very rapid. By the end of two weeks the seed is more than two-thirds the mature size, while the zygote has divided only once and there is only moderate development of the endosperm. The entire cavity within the integuments is filled with thin walled nucellar tissue.

According to Maneval (3) the mature female gametophyte of *Liriodendron tulipifera* has the seven cells typical of many of the Angiosperms. The antipodals disintegrate early and shortly after the flower opens there is left only the egg cell and the endosperm nucleus with remnants of the two synergids.

The time of pollination of the flowers from which this study was made was between June second and fourth. Sections of ovules made one week later showed a very limited development of the endosperm, but no development of the embryo. The seed had about doubled in size during this week.

By June 18th, approximately two weeks after pollination, the seed had enlarged to about six times the length of the ovule and was almost twice as wide. Except for the portion of the seed now occupied by the endosperm the part inclosed by the integuments was filled with thin walled cells of the nucellus. The endosperm consisted of a narrow tissue four cells in diameter extending from the micropilar end of the ovule two-thirds of the way back through the nucellar tissue. The zygote had divided only once.

On July 1 (fig. 1) the endosperm filled almost the entire cavity with only a small portion of nucellar tissue left which had not been absorbed. The integuments were beginning to harden although they could still be cut in paraffin without special softening.

The embryo (fig. 2) at this time consisted of a short suspension and a group of cells with little or no differentiation evident.

The next observations made on August 12th showed the endosperm almost completely filled the seed cavity with only remnants of the nucellus. The embryo (fig. 3) had developed to about one-third mature size and the cotyledons were beginning to become evident. At this time there was some accumulation of stored food in the endosperm.

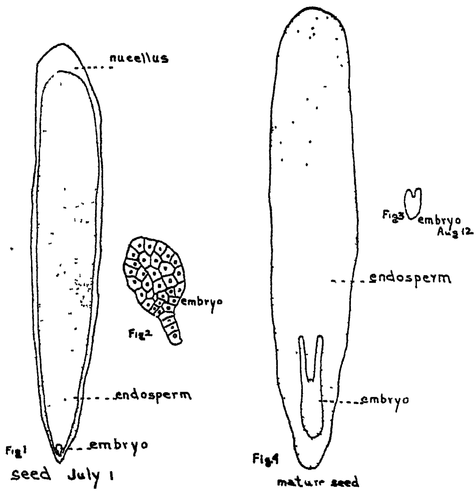

Figure 4 shows a median section of a mature seed at the time they were being dispersed naturally from the tree. The hypocotyl and cotyledons were well developed, but there was very little development of the epicotyl. Much stored food was present in the endosperm.

The seed must be stratified through the winter for spring germination but seed taken out of stratification in early March showed no evident morphological changes over the mature seed.

In a very large number of seed there is no evidence of embryo and endosperm development. This seems to indicate that failure of fertilization or early failure of the embryo to develop or both must be the case. In most of these seed there is, however, this same rapid development of the integuments and nucellar tissue as in seeds which develop embryo and endosperm.

Brink and Cooper (1) assigned the cause of failure of some seed to develop to the fact that there is severe competition between the new plant and surrounding tissue for food in the early stages of development. If this is true the very rapid development of integuments and nucellar tissue in the seed of the tulip tree may result in starvation of the zygote.

In alfalfa Brink and Cooper (1) found that cross fertilization resulted in a much reduced failure of seed to develop. Landes (2) also found that one of the principal causes of self-sterility in rye was failure of the embryo and endosperm to develop after self-fertilization.

There is also evidence that failure of seed in the tulip tree may be due to self-pollination. Of approximately 800 seed from cones, self-pollinated by hand, only 11.7 per cent showed filled seed. While the same number from the same tree, pollinated by hand, with pollen from a tree some twenty miles distant showed 38.9 per cent filled seeds.

Conclusions: The development of the seed of the tulip tree is slow. It reaches morphological maturity between August 12 and September 15; probably not before September 1.

It is doubtless better not to gather seed for planting until after the first week in September, although the fruits look mature by the middle of August.

Cross pollination, in the limited number of cases tried, did increase the per cent of good seed more than three times.

It may be better to mix seed from various sources when reforesting, causing a mixed population and possibly better natural reseeding.

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A Leaf Spot of *Ginkgo biloba*

C. L. PORTER, Purdue University

Ginkgo biloba is increasingly more popular as a street, park, and specimen tree. This plant has many things to commend it. Historically, it is very ancient, having originated probably in the Permian. Ernest H. Wilson (4) says, "The ginkgo is a vertiable living fossil." At one time the family to which the ginkgo is a member was widespread throughout the northern hemisphere. During the glacial epoch, the family became restricted to the Orient and it is probable that at this time all species except biloba became extinct. The tree was found in China mentioned in the very earliest records from that country. According to Wilson the tree reached Japan with Buddhism in the sixth century and it is in Japan that the finest specimens are known today, some being over one thousand years old. Ginkgo biloba was probably introduced into Europe by traders of the Dutch East Indian service. The tree arrived in England about 1750 and the first of the species to flower in Europe was in Kew Gardens in 1795. The species was imported to North America from England in 1784, when a tree was planted at Woodlands near Philadelphia. The tree still survives as a very fine specimen. During human history *Ginkgo biloba* has not been known to exist in the wild state.

Botanically, the ginkgo presents many oddities that are appealing to the lover of plants. The fruit is a naked fruit. The egg is fertilized with a motile sperm, and according to John H. Schaffner (1) the plant does not produce flowers but sporophylls. Schaffner says, "Ginkgo is not only our only surviving, completely flowerless seed plant, but it is probably the highest flowerless seed plant that ever evolved."

Shade tree experts in the past have recognized the ginkgo tree as desirable for the following reasons:

a) Long life.

b) Well-shaped symmetrical tree becoming more desirable in these respects as it grows older.

c) Odd shaped distinctive leaves which are transformed to a uniform golden color with the approach of the frosts of autumn.

d) Leaves remain well attached until late, therefore do not produce litter.

e) Thrives under unfavorable urban conditions.

f) Absence of insect enemies.

g) Absence of fungus enemies.

The last statement emphasized by Piorne, Pack and Rankin in their various works must now be revised.

In the late summer of 1939 a severe epidemic of leaf spot and blight occurred on various ginkgo trees on the Purdue campus and considerable defoliation was noted. The disease lesions frequently occur as isolated

spots on the leaf. These spots originate as water-soaked patches and develop into irregular areas that finally are ashen in the center with a dark reddish-brown border. Such spots may occur in any location on the leaf and are not limited by the radiating vascular bundles. More often the disease makes its appearance at the outer margin of the leaf and sweeps inward from the margin to the petiole. These areas thus become wedge-shaped and uniformly tan in color. Dark colored pycnidia are often found scattered rather sparsely over old leaf lesions. It is unusual for the petiole to be involved. At times so much of the leaf area is involved that the disease should properly be termed a blight rather than a spot. Often the tissues not directly involved turn golden yellow, apparently being affected by exotoxins produced by the causal organism. Many affected leaves drop early and belie the tree's reputation for tidiness. However, many affected leaves remain on the tree and are not shed earlier than normal leaves. A diseased tree then, exhibits an unsightly discoloration of the foliage in the late summer and early fall. Fruits may be spotted.

The disease has occurred each Summer since 1939 and some trees have been severely blighted each season. It is a curious fact that not all trees are attacked and those that gave no evidence of the disease this season have not done so in previous seasons. This may indicate that some trees are less susceptible, or it may be another example of "disease escape". The author is inclined to believe that there exists degrees of susceptibility in these trees because there appears to be gradations in severity of attack from complete immunity, through lightly affected trees, to specimens having almost every leaf spotted or blighted. This gradation has appeared in the same trees during the seasons of observation since 1939.

In the progressive disintegration of the leaf tissues, the parenchymatous-like tissues seem to be first involved and soon collapse. The pallisade layer is somewhat more resistant but soon follows the parenchyma cells in collapse. The cells of the epidermal tissues retain a normal appearance until the final stages of the disease. This is particularly true of the cells of the lower epidermis which are characterized by having slight protuberances that are heavily cutinized. This line of heavy protuberances remains visible and intact in cross sections after other tissues have completely collapsed. The vascular bundles are but little affected; the sheath cells being first to exhibit injury. In the final stages of necrosis the leaf tissues in cross section are represented by the two heavily cutinized lines of the epidermis.

Seymour (2) in the Host Index of the Fungi of North America reports *Glomerella cingulata* isolated from *Ginkgo biloba.*

Freeman Weiss (3) in the Plant Disease Reporter (May, 1941) reports the following fungi isolated from leaves of Ginkgo biloba:

a) *Glomerella cingulata*
b) *Phyllosticta ginkgo*

Pycnidia are found in many older lesions on the ginkgo leaves and Phyllosticta-type spores have been obtained from the pycnidia. It seems

probable that the leaf spot of Ginkgo here described is therefore caused by Phyllosticta ginkgo. Efforts made to isolate the causal organism have not been altogether successful. The necrotic areas of the rather fleshy leaves support a number of saprophytes and must be separated from the causal agent in culture. If Phyllosticta has been isolated the cultures have not produced characteristic pycnidia and spores to date. An interesting and promising Gloesporium has been repeatedly isolated from necrotic areas but there exists no proof that this organism is associated with the disease.

Seedlings propagated from seeds have been growing in our greenhouse for a number of years and the leaves have never become affected in any manner. So far it has been impossible to produce leaf spot symptoms on the leaves of these seedlings from any of the organisms isolated in culture.

This disease is not serious enough to affect the vitality of the plant but it is serious enough to detract from an otherwise almost perfect tree.

References

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2. Seymour, Arthur Bliss. *Host index of the fungi of North America.* Harvard University Press, Cambridge, Mass., 1929.

3. Weiss, Freeman. Check list revision. The Plant Disease Reporter, **25**:223, 1941.

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Lichens Known from Indiana

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The study of Indiana lichens has been sadly neglected, if one may judge by the published records. Only four short papers specifically mentioning Indiana lichens are known to me. Apparently, Dr. L. M. Underwood was the first to publish anything on Indiana lichens, giving thirty species in his "List of Cryptogams at Present Known to Inhabit the State of Indiana." This was published in the Proceedings of the Indiana Academy of Science for 1893. W. W. Calkins included a part of Lake County, Indiana, in his "Lichen Flora of Chicago and Vicinity," but failed to indicate the species occurring in Lake County. Bruce Fink and Sylvia Fuson listed 57 species of lichens in their paper "Ascomycetes New to the Flora of Indiana," published in the Indiana Academy of Science Proceedings for 1918. Fink lists a paper entitled "Lichens of Indiana," by W. H. Evans, read before the Indiana Academy of Sciences in 1887. It was said to have been published, but Fink was unable to locate any such publication. In The American Midland Naturalist, January, 1943, I reported upon a few lichens from the DePauw University Herbarium, mostly collected by Dr. Winona H. Welch.

It is self-evident that the lichens here given are but a small part of the total lichen flora of Indiana, but the list is presented in the hope that the botanists of the State will be stirred to some interest in these strange and sadly neglected plants. I have failed to locate any collections of Indiana lichens other than the one at DePauw University.

This apathy is unjustifiable, for no group of plants will better repay study, and certainly the puzzles presented by lichens are not exceeded by those found in any other group. The Cladonias are perhaps the most striking example of evolution here and now known to naturalists. For over fifty years they have been cited as the classic example of evolution going on before our eyes. In the opinion of some botanists lichens present to the student of heredity the most arrant contradictions and some of the greatest puzzles of the plant world. Their life contraverts much that is written on genetics, but as yet no geneticist has taken up seriously the study of heredity and variation in lichens.

A lichen is a physiological species, and not a species in the sense that cabbages, coconuts, and corn flowers are. Without the controlling apparatus of most plants, heredity in lichens and their responses to environment are as real and perceptible as in any other organisms. No chromosomes control lichen heredity, for a lichen is a composite. In spite of that, a lichen is a definite entity whose characters are somehow transmitted. At the same time it is able to respond to environmental demands. Lichens are highly plastic organisms, within their limits, and are ideal for studying ecology. They are equally well adapted for the

study of many physiological problems, both in the field and in the laboratory.

The present paper is based upon the study of the lichen collection in the DePauw University Herbarium, with the exception of most of the Cladoniaceae, which had already been determined by Dr. A. W. Evans and R. H. Torrey. It is due to the active cooperation and energy of Dr. Welch that this contribution to a knowledge of Indiana lichens and their distribution has been made. Without her untiring zeal this paper would not have been possible. Dr. Charles C. Deam, dean of Indiana systematic botanists, made a small collection of lichens at the request of the late Dr. C. C. Plitt. Dr. Deam kindly gave me a list of the species determined by Dr. Plitt. A few unnamed specimens in the DePauw Herbarium were named by me, and some unnamed parmelias were identified by Dr. E. C. Berry. Full use was made of the lists published by Dr. L. M. Underwood and Dr. Bruce Fink. Dr. Berry's monograph of the genus *Parmelia* in North America north of Mexico gave species and localities not otherwise known from Indiana, and Fink's Lichen Flora yielded additional records. It is hoped that no lichens published as occurring in Indiana have been omitted. Where no one is indicated as naming a species, it has been identified by me.

The present list includes 121 species and named varieties. Where forms of species have been identified, they are listed under the species or variety to which they belong but are not given separate numbers. Specimens of all the lichens here named are in the DePauw University Herbarium, except specimens named by Dr. Bruce Fink, Dr. C. C. Plitt, and Dr. E. C. Berry. I have examined all the lichens in the DePauw University Herbarium except those named by Dr. Evans and Dr. Torrey, and am responsible for the list as it appears here. (DP.) indicates specimens now in the DePauw University Herbarium.

Verrucariaceae

Verrucaria nigrescens Persoon—On limestone boulders, Montgomery, Putnam, and Tippecanoe Counties. Fink.

Verrucaria rupestris Schrader—On exposed sandstone, limestone, and bricks, in Franklin, Monroe, Montgomery, and Putnam Counties. Fink.

Verrucaria sordida Fink—On limestone boulders, Montgomery County. Fink.

Verrucaria viridula Acharius—On rock, Montgomery County. Fink.

Thelidium microbolum (Tuck.) Hasse—Collected at the first bend in road 37, north of Bloomington, Monroe County. Spores colorless, bilocular to quadrilocular, 8-11 by 21-31 μ. Det. Herre.

Thrombium epigaeum (Pers.) Wallroth—On soil in Sayre's Wood, Union County. Fink.

Pyrenulaceae

Microthelia micula Koerber—On cultivated cherry bark, Sayre's Wood, Union County. Fink.

Pyrenula farrea (Ach.) Br. & Rostr.—On beech bark, woods at Turkey Run, Parke County. Fink.

Pyrenula nitida (Weig.) Ach.—On trees, Turkey Run, Parke County. Fink.

Dermatocarpaceae

Dermatocarpon miniatum (L.) Mann—a.—On limestone, fork of Clear Creek, near Harrodsburg, Monroe County. Welch Coll., No. 1920. Det. Herre. (DP.) b.—Bean Blossom Woods, northwest of Bloomington, near Griffy Creek Bridge, Monroe County. Welch Coll., No. 1925. Det. Welch; Herre. (DP.) c.—Eel River Falls, Owen County, October, 1893; Coll. and det. L. M. Underwood. (DP.) d.—On rock, 8 miles north of Bedford, Lawrence County. Coll. Nattkemper, May 12, 1935. Det. Herre. (DP.) e.—On limestone, one-half mile north of Vernon, along North Fork of Muscatatuck River, Jennings County. Coll. Welch, Nos. 7441 and 7448. Det. Herre. (DP.) f.—Limestone ledge, east of Amsterdam, Harrison County. Coll. Welch, No. 5239. Det. Torrey. Checked, Herre. (DP.) g.—On bare, hard, open portion of chicken lot, 3 miles northeast of Goodland, Jasper County. Coll. Welch, No. 2255. Det. Evans. (DP.) h.—Jones' Falls, 5 miles northwest of Greencastle, Putnam County, May 22, 1897. Det. checked by Herre. (DP.)

Endocarpon pusillum Hedwig—On bounders, Franklin, Montgomery, and Union Counties. Fink.

Trypetheliaceae

Trypethelium virens Tuck.—On beech bark, Tippecanoe County. Fink.

Arthoniaceae

Arthonia dispersa (Schrader) Nylander—On maple bark, Montgomery and Union Counties. Fink.

Arthonia lecideella Nyl.—On trees, Hendricks, Montgomery, Parke, Tippecanoe, and Union Counties. Fink.

Arthonia radiata (Pers.) Ach.—On basswood trees, Tippecanoe County. Fink.

Allerthonia lapidicola (Taylor) A. Zahlbr.—On sandstone, "Indiana," in Fink's Lichen Flora.

Arthothelium spectabile Mass.—Common, on beech trees, near Fern, Putnam County. Coll. Ralph C. Norton, April 19, 1894. Det. Herre. (DP.) Thallus brownish, off color, asci mostly sterile, spores finally muriform, 10-13 by 22.5-30 μ.

Graphidiaceae

Opegrapha varia Pers.—On trees, Parke and Tippecanoe Counties. Fink.

Graphis scripta (L.) Ach.—Fern, Putnam County. Coll. and det. Underwood, October, 1891. Checked, Herre. (DP.)

Pyrenopsidaceae

Pyrenopsis fuscoatra Fink—On limestone, Montgomery County. Fink.

Collemaceae

Collema nigrescens (Hudson) DC. a.—Specimens sterile; on trees in Salt Creek Swamp, 12 miles southeast of Bloomington, Monroe County, Welch, No. 1924, and east of Vernon, Jennings County, Welch, No. 7460. Det. Herre. (DP.) b.—On white walnut, 5 miles north of Bedford, on state road 37, Lawrence County. Coll. Earl L. Harger, Jr., May 12, 1935. Det. Herre. (DP.)

Collema pycnocarpum Nyl.—On a tree trunk, Cedar Cliff, near Harrodsburg, Monroe County. Spores 3-4.7 by 10-12.5 μ. Coll. Welch, No. 1915. Det. Herre. (DP.)

Collema ryssoleum Tuck.—Spores quadrilocular. On rock, 7 miles north of Bedford, Lawrence County. Coll. Nattkemper, May 12, 1935. Det. Herre. (DP.)

Leptogium chloromelum (Swartz) Nyl.—a.—On oak trunk in woods one-half mile north of Vernon, Jennings County, along Muscatatuck River, North Fork. Coll. Welch, No. 7444. Det. Herre. (DP.) b.—A juvenile *Leptogium*, probably *L. chloromelum.* On limestone under ledge near Cataract Falls, Owen Park, Owen County. Coll. Welch, No. 6262. Det. Herre. (DP.)

Leptogium dactylinum Tuck.—Sandstone ledge, Fern, Putnam County, 7 miles west of Greencastle. Coll. Welch, No. 5493. Det. Herre. (DP.)

Leptogium juniperinum Tuck.—Spores 7-9 by 15.5-24 μ. On cedar bark, Schooner's Point, Crawford County. Coll. Welch, No. 7450. Det. Herre. (DP.)

Leptogium lichenoides (L.) A. Zahlbr.—Sterile. On dry exposed limestone, Geode Gorge, 6 miles east of Greencastle, Putnam County. Welch Coll., No. 7838. Det. Herre. (DP.)

Leptogium lichenoides (L.) A. Zahlbr. vr. *pulvinatum* (Hoffm.) A. Zahlbr.—On limestone, Cataract Falls, Owen County. Welch Coll., No. 5252. Det. R. H. Torrey. (DP.)

Leptogium pulchellum (Ach.) Nyl.—a.—On a fallen tree, east of Vernon, Jennings County, along the Muscatatuck River. Welch Coll., No. 7449. Det. Herre. (DP.)

Leptogium tremelloides (L.) S. F. Gray—On mossy rocks, Montgomery County. Fink.

Stictaceae

Lobaria pulmonaria (L.) Hoffm.—a.—Eel River Falls, Owen County. Coll. and det. Underwood, October, 1893. Checked, Herre. (DP.) b.—Fern, Putnam County. Coll. L. M. Underwood, April, 1893. Det. Herre. (DP.)

Sticta weigeli (Ach.) Wainio—Perry County. Coll. C. C. Deam, No. 51508. Det. Plitt.

Peltigeraceae

Peltigera canina (L.) Willd.—a.—On earth, on an oak slope along a creek in Sec. 26, about 2 and ½ miles southeast of Peppertown, Franklin County. Coll. C. C. Deam, No. 58029. Det. Herre. (DP.) b.—On soil at Cedar Cliff, near Harrodsburg, Monroe County. Welch Coll., No. 1916. Det. Herre. (DP.) c.—On sandstone, Sword Moss Gorge, near Fallen Rock, 14 miles west of Greencastle, Parke County. Welch Coll., No. 7458. Det. Herre. (DP.) d.—On moss and soil, DePauw University Arboretum, near Greencastle, Putnam County. Coll. Nattkemper, May 22, 1936. (DP.)

Peltigera horizontalis (Huds.) Baumg.—a.—Near Bloomington, Monroe County. Coll. Welch, No. 7431. Det. Herre. (DP.) b.—On rocks at The Shades, Montgomery County. Fink.

Peltigera malacea (Ach.) Funck—On soil, near Bloomington, Monroe County. Coll. Welch, No. 7468. Det. Herre. (DP.)

Peltigera polydactyla (Neck.) Hoffm.—a.—On limestone, among mosses, and mixed with *Cladonia* and *Physcia*, one-half mile north of Vernon, Jennings County, along North Fork of Muscatatuck River. Coll. Welch, No. 7436. Det. Herre. (D.P.) b.—On rocks, near north stile, DePauw University Arboretum, Putnam County, mixed with *P. canina*. Coll. Welch, No. 5573. Det. Herre. (DP.)

Peltigera praetextata (Sommerf.) Wainio—a.—On limestone, one-half mile north of Vernon, Jennings County, along North Fork of Muscatatuck River. Coll. Welch, No. 7438. Det. Herre. (DP.) b.—On tree roots, same locality as "*a*." Welch Coll., No. 7439. Det Herre. (DP.) c.—Base of tree trunk, bank of stream, Fern, Putnam County, 7 miles west of Greencastle. Coll. Welch, No. 5494. Det. Herre. (DP.) d.—On limestone, in woods, Hoosier Highlands, Putnam County. Coll. Welch, No. 2251. Det. Herre. (DP.) e.—On limestone in woods, Tippecanoe County. Fink.

Peltigera praetextata (Sommerf.) Wainio var. *isidiata* (Timko) Gyelnik—On sandstone, Fern, Putnam County, 7 miles west of Greencastle. Coll. Welch, No. 7837. Det. Herre. (DP.)

Peltigera rufescens (Weiss) Humboldt.—a.—Perry County. Deam Coll., No. 46747. Det. Plitt. b.—On a rotten log, low rich woods, 2 miles north and 2 and ½ miles east of Kingsland, Wells County. Coll. C. C. Deam, No. 14481A. Det. Welch; Herre. (DP.) c.—On sandstone ledge, on west side of White River, one-half mile above Shoals, Martin County. Coll. Deam, No. 11421A. Det. Herre. (DP.) d.—On the ground under a pin oak, in woods about 2 miles north of Livonia, Washington County. Coll. C. C. Deam, No. 56329. Det. Herre. (DP.) This same number has been determined as *Peltigera spuria* by Dr. C. C. Plitt. The collection must have been of mixed material, a circumstance often occurring in collecting lichens.

Peltigera spuria (Ach.) DC.—a.—Crawford County. Coll. C. C. Deam, No. 52619. b.—Washington County. Coll. Deam, No. 56329. Both determined by Dr. C. C. Plitt.

Lecidaceae

Lecidea coarctata (J. E. Smith) Nyl.—On bricks and moist rocks, Crawford's Wood, Montgomery County. Fink.

Lecidea vulgata A. Zahlbr.—On rocks, Union County. Fink, as *Lecidea enteroleuca* Ach.

Lecidea myriocarpoides Nyl.—On a rotten stump, Indiana University Campus Wood. Fink.

Lecidea uliginosa (Schrad.) Ach.—On rotten stumps, in Hendricks, Montgomery, and Union Counties. Fink.

Lecidea Russelli Tuck.—Specimens sterile and scanty. On limestone, Cedar Cliff, near Harrodsburg, Monroe County. Coll. Welch, No. 1917. Det. Herre. (DP.)

Bacidia inundata (E. Fr.) Koerber—On moist bricks and rocks, Monroe, Montgomery, Putnam, Tippecanoe, and Union Counties. Fink.

Bacidia luteola (Schrad.) Mudd—On willows, Tippecanoe County. Fink, as *Bacidia rubella*.

Bacidia Schweinitzi (Tuck.) Schneider—On beech trees, Sayre's Woods, Union County. Fink.

Rhizocarpon albineum (Tuck.)—"Indiana," in Fink's Lichen Flora.

Cladoniaceae

Cladonia bacillaris (Del.) Nyl.—a.—On stumps in open pasture, Hendricks County. Fink. b.—On rotten stump, Highway 37, 7 miles north of Bedford, Lawrence County. Coll. Nattkemper, May 12, 1935. Det. Dr. A. W. Evans. (DP.)

Cladonia bacillaris f. *abbreviata* (Wainio.) Harm.—Log along ravine, one-half mile south of Freedom, Owen County. Coll. Welch, No. 2209. Det. Evans. (DP.)

Cladonia barbonica (Del.) Nyl. f. *cylindrica* Evans—a.—On rotten stump, Highway 37, 7 miles north of Bedford, Lawrence County. Coll. Clark Nattkemper, May 12, 1935. Det. A. W. Evans. (DP.) b.—On base of a live tamarack tree in large bog about 2 miles north of Pinhook, about 6 miles west of Laporte, Laporte County. Coll. Chas. C. Deam, No. 56050. Det. Evans. (DP.) c.—On dry, shaded log, McCormick's Creek State Park, river road, Owen County. Coll. Welch, No. 5242. Det. Torrey. (DP.)

Cladonia caespiticia (Persoon) Floerke—a.—Crawford County. Coll. Deam, No. 52621. Det. Plitt. b.—Woods, on elm trunk, Dubois County. Coll. Welch, No. 5240. Det. R. H. Torrey. (DP.)

Cladonia cariosa (Ach.) Sprengel—a.—On soil, in Crawford's Woods, Montgomery County. Det. Fink. b.—On soil, near Martinsville, Morgan County. Coll. Welch, No. 7454. Det. Herre. (DP.)

Cladonia chlorophaea (Floerke) Spreng.—a.—Wooded bank along Cedar Creek, about 2 miles north of Cedarville, Allen County. Coll. Deam, No. 14286. Det. Evans. (DP.) b.—On base of a live tamarack tree in large bog about 2 miles north of Pinhook, about 6 miles west of Laporte, Laporte County. Coll. Chas. C. Deam, No. 56050 and 56049. Det. Evans. (DP.) c.—About old tamarack stump in clearing west side of Wolf Lake, Noble County. Coll. Chas. C. Deam, No. 14730A. Det. Evans. (DP.) d.—Soil, head of Bloomington Water Works Lake, Monroe County. Col. Welch, No. 2208. Det. Evans. (DP.) e.—Pine Hills, Montgomery County. Coll. Welch, No. 7839. Det. Herre. (DP.)

Cladonia chlorophaea f. *simplex* (Hoffm.) Arnold—a.—Sandstone soil, Scout Camp, Portland Arch, Fountain County. Coll. Welch, No. 5243. Det. R. H. Torrey. (DP.) b.—Soil, wooded bank of Big Creek, about 14 miles northwest of Hanover, Jefferson County. Coll. Welch, No. 5247. Det. Torrey. (DP.) c.—Edge of rim of quarry, on limestone, McCormick's Creek State Park, Owen County. Coll. Welch, No. 5249. Det. Torrey. (DP.) d.—On soil, wooded ridge, along Eel River, Owen Park, Owen County. Coll. Welch, No. 5254. Det. Torrey. (DP.) e.—Sandstone, De Weir Woods, Perry County, near Cannelton. Coll. Welch, No. 5245. Det. Torrey. (DP.) f.—Soil, wooded slope, oak-hickory woods, 10 miles east of Salem, Washington County. Coll. Welch, No. 5235. Det. Torrey. (DP.) g.—Soil, 10 miles east of Salem, Washington County. Coll. Welch, No. 5250. Det. Torrey. (DP.)

Cladonia coniocraea (Floerke) Sandstede—a.—On rail fences and old logs, Hendricks, Montgomery, Tippecanoe, and Union Counties. Fink. b.—Beanblossom Woods, northwest of Griffy Creek Bridge, 6 miles north of Bloomington, Monroe County. Coll. Flora Anderson, December 15, 1929. Det. Anderson; Herre. (DP.) c.—On soil, The Shades, Montgomery County. Coll. Welch, No. 7456. Det. Herre. (DP.) d.—On

decaying log, on wooded slope, Fern, 7 miles west of Greencastle, Putnam County. Coll. Welch, No. 5497. Det. Herre. (DP.) e.—Near Fern, Putnam County. Coll. Ralph C. Norton, May 10, 1894. Det. Herre. (DP.) f.—Base of white oak tree, Eel River bank, Owen Park, Owen County. Coll. Welch, No. 5251. Det. Torrey. (DP.)

Cladonia coniocraea (Floerke) Sandst. f. *ceratodes* Dalla T. & Sarnth. —a.—On sandstone soil, woods, Dubois County. Coll. Welch, No. 5234. Det. Torrey. (DP.) b.—On decaying log, in oak woods, 3 miles south of Hanover, Jefferson County. Coll. Welch, No. 5246. Det. Torrey. (DP.) c.—On decaying log, oak-hickory woods, 10 miles east of Salem, Washington County. Coll. Welch, No. 5248. Det. Torrey. (DP.)

Cladonia cristatella Tuckerman—a.—On soil, near Bloomington, Monroe County. Coll. Welch, No. 7466. Det. Herre. (DP.) b.—On soil, Pine Hills, Montgomery County. Coll. Welch, No. 7842. Det. Herre. (DP.) c.—On soil near Martinsville, Morgan County. Coll. Welch, No. 7453. Det. Herre. (DP.) d.—On soil in oak-hickory woods, near Martinsville, Morgan County. Coll. Welch, No. 7452. Det. Herre. (DP.) e.—Sandy hill in woods, vicinity of Huckleberry, Steuben County. Coll. Chas. C. Deam, September 9, 1903. Det. Herre. (DP.) f.—Richmond, Wayne County. Coll. Mrs. Mary P. Haines. Det. Herre. (DP.)

Cladonia cristatella Tuck. f. *beauvoisi* (Delise) Wainio—a.—On soil, Bloomington Water Works Lake, Monroe County. Coll. Welch, No. 2210. Det. Evans. (DP.) b.—Top of bank at Hemlock Bluffs on Raccoon Creek, about 6 miles south of Spencer, Owen County. Coll. Chas. C. Deam, No. 10207. Det. Evans. (DP.) c.—Steuben County. Coll. Deam, No. 52454. Det. Plitt.

Cladonia cristatella Tuck. f. *ochrocarpia* Tuck.—On soil, near Martinsville, Morgan County. Coll. Welch, No. 7452. Det. Herre. (DP.)

Cladonia cristatella Tuck. f. *vestita* Tuck.—a.—Jefferson County. Coll. C. C. Deam, No. 53410C. Det. Plitt. b.—On soil, head of Bloomington Water Works Lake, Monroe County. Coll. Welch, No. 2205. Det. Evans. (DP.) c.—Ditto, No. 2210. Det. Evans. (DP.) d.—On soil, near Bloomington, Monroe County. Coll. Welch, No. 7467. Det. Welch; Herre. (DP.) e.—Steuben County. Deam Coll., September 9, 1903. Det. Evans. (DP.) f.—Switzerland County. Deam Coll., No. 58114B. Det. Torrey. (DP.) g.—On decayed wood, oak-hickory association, 10 miles east of Salem, Washington County. Coll. Welch, No. 5238. Det. Torrey. (DP.) h.—"Indiana." Deam Coll., No. 56049. Det. Evans. (DP.)

Cladonia fimbriata (L.) E. Fr.—On decaying log, in woods one-half mile north of Vernon, Jennings County, along North Fork of Muscatatuck River. Coll. Welch, No. 7518. Det. Herre. (DP.)

Cladonia fimbriata f. *conista Oliv.* s.f. *simplex* A. Zahlbr.—On limestone, on south-facing slope of Cedar Cliff, near Harrodsburg, Monroe County. Coll. Welch, No. 1922. Det. Evans. (DP.)

Cladonia fimbriata var. *simplex* (Weiss) Flotow—a.—On decaying log, in woods one-half mile north of Vernon, Jennings County, along North Fork of Muscatatuck River. Coll. Welch, No. 7518. Det. Herre. (DP.) b.—Pigeon River, sand dune, Lagrange County. Coll. Welch, No. 7451. Det. Herre. (DP.) c.—On soil, The Shades, Montgomery County. Coll. Welch, No. 7456. Det. Herre. (DP.)

Cladonia furcata var. *corymbosa* (Ach.) Nyl.—Upland soil, in beech woods along Saluda Creek, a quarter mile south of Saluda School, Jefferson County. Coll. Welch, No. 5241. Det. by Torrey as *C. furcata* var. *racemosa* f. *corymbosa.* (DP.)

Cladonia furcata var. *pinnata* (Floerke) Wainio—Wooded bank along Cedar Creek, about 2 miles north of Cedarville, Allen County. Coll. Deam, No. 14286. Det. Evans. (DP.)

Cladonia furcata var. *pinnata* f. *foliosa* Del.—On rim of quarry, in shade, McCormick's Creek State Park, Owen County. Coll. Welch, No. 5236. Det. Torrey. (DP.)

Cladonia furcata var. *racemosa* (Hoffm.) Floerke—In open dry woods, State Reserve, Clark County. Coll. C. C. Deam, No. 5398. Det. Evans. (DP.)

Cladonia furcata (Huds.) Schrad. var. *racemosa* (Hoffm.) Floerke f. *squamulifera* Sandst.—a.—On limestone, on south-facing slope, Cedar Cliff, near Harrodsburg, Monroe County. Coll. Welch, No. 1921. Det. Evans. (DP.) b.—On dry wooded slope, Pine Hills, Montgomery County. Coll. Welch, No. 2197. Det. Evans. (DP.) c.—Hoosier Highlands, Putnam County. Coll. Welch, No. 2207. Det. Evans. (DP.) d.—On soil, 13 miles east of Boonville, Warrick County. Coll. Clark Nattkemper, May 11, 1935. Det. Evans. (DP.)

Cladonia grayi Merrill—a.—On soil, 13 miles east of Boonville, Warrick County. Coll. Clark Nattkemper, May 11, 1935. Det. Evans. (DP.) b.—Pastured waste land, shade of huckleberries or in open. White County. Coll. Welch, No. 2199. Det. Evans. (DP.)

Cladonia grayi pp. f. *squamulosa* Sandst.—On ground in sandy woods near Huckleberry, Steuben County. Coll. C. C. Deam, September 9, 1903. Det. Evans. (DP.)

Cladonia macilenta Hoffm.—a.—On decaying log, in woods one-half mile north of Vernon, Jennings County, along North Fork of Muscatatuck River. Coll. Welch, No. 7517. Det. Herre. (DP.) b.—On rail fences and old logs, Montgomery, Tippecanoe, and Union Counties. Fink.

Cladonia mitrula Tuckerman—a.—In woods one-half mile south of Lake Cicott, Cass County. Coll. Welch, No. 5576. Det. Herre. (DP.) b.—On log in woods, one-half mile north of Vernon, Jennings County, along North Fork of Mucatatuck River. Coll. Welch, No. 7434. Det. Herre. (DP.) c.—On limestone, one-half mile north of Vernon, Jennings County, along North Fork of Muscatatuck River. Coll. Welch, No. 7436. Det. Herre. (DP.) d.—On decaying log, in woods, one-half mile north

of Vernon, Jennings County along North Fork of Muscatatuck River. Coll. Welch, No. 7440. Det. Herre. (DP.) e.—On tree trunk, one-half mile north of Vernon, Jennings County, along North Fork of Muscatatuck River. Coll. Welch, No. 7443. Det. Herre. (DP.) f.—On soil, in woods, one-half mile north of Vernon, Jennings County, along North Fork of Muscatatuck River. Coll. Welch, No. 7445. Det. Herre. (DP.) g.—On rotten wood, tree trunk, one-half mile north of Vernon, Jennings County, along North Fork of Muscatatuck River. Coll. Welch, No. 7516. Det. Herre. (DP.) h.—On soil, The Shades, Montgomery County. Coll. Welch, No. 7455. Det. Herre. (DP.)

Cladonia mitrula Tuck. f. *imbricatula* (Nyl.) Wainio—a.—On a tree, west of Alpine, Fayette County. Coll. Floyd Shuttleworth, March, 1932. Det. Evans. (DP.) b.—On limestone, McBride Bluffs, near Shoals, Martin County. Coll. Welch, No. 5237. Det. Torrey. (DP.) c.—On an old stump, on road between Elletsville and Spencer, Owen County. Coll. Nattkemper, May 12, 1935. Det. Evans. (DP.) d.—On soil, wooded ridge, Eel River, Owen Park, Owen County. Coll. Welch, No. 5253. Det. Torrey. (DP.) e.—Roadside cut, woods, 4.7 miles northwest of Mt. Vernon, Posey County. Coll. Deam, No. 22870. Det. Evans. (DP.) f.—On soil on slope in wooded pasture, 5 and ½ miles south of Greencastle, Putnam County. Coll. Welch, No. 5256. Det. Torrey. (DP.)

Cladonia mitrula f. *squamulosa* Merrill—On dead log along road to Hovey Lake, Mt. Vernon, Posey County. Coll. Clark Nattkemper, May 11, 1935. Det. Evans. (DP.)

Cladonia piedmontensis Merrill f. *obconica* Robbins—On soil, 13 miles east of Boonville, Warrick County. Coll. Clark Nattkemper, May 11, 1935. Det. Evans. (DP.)

Cladonia pyxidata (L.) Hoffm.—a.—On soil, The Shades, Montgomery County. Coll. Welch., No. 7456. Det. Herre. (DP.)

Cladonia pyxidata (L.) Hoffm. f. *simplex* (Ach.) Harm.—On soil on slope in wooded pasture, 5 and ½ miles south of Greencastle, Putnam County. Coll. Welch, No. 5255. Det. Torrey. (DP.)

Cladonia rangiformis Hoffmann—Near Greencastle, Putnam County. Det. Herre. (DP.)

Cladonia subcariosa (Nyl.) Wainio—a.—Daviess County. Coll. C. C. Deam, No. 52713. Det. C. C. Plitt. b.—Jefferson County. Coll. C. C. Deam, No. 53410D. Det. C. C. Plitt. c.—On soil, 13 miles east of Boonville, Warrick County. Coll. Clark Nattkemper, May 11, 1935. Det. Evans. (DP.)

Cladonia subcariosa p. *max.* p.f. *evoluta* Wainio—Open, dry, grassy habitats, head of Bloomington Water Works Lake, Monroe County. Coll. Welch, No. 2211 and No. 2296. Det. Evans. (DP.)

Cladonia symphycarpa (Ach.) E. Fr.—Fern, Putnam County, 7 miles west of Greencastle. Coll. and det. L. M. Underwood, April, 1893. Checked, Herre. (DP.)

Cladonia tenuis Harm.—a.—On soil, ridge, Scout Camp, Portland Arch, Fountain County. Coll. Welch, No. 5244. Det. Torrey. (DP.) b.—Franklin County. Coll. C. C. Deam, No. 47317. Det. Plitt. c.—On open dry ground, head of Bloomington Water Works Lake, Monroe County. Coll. Welch, No. 2202. Det. Evans. (DP.) d.—Hoosier Highlands, Putnam County. Coll. Welch, No. 6002. Det. Evans. (DP.) e.—On soil, 13 miles east of Boonville, Warrick County. Coll. Clark Nattkemper, May 11, 1935. Det. Evans. (DP.) f.—Pastured waste land, shade of *Quercus alba*, Princeton Township, White County. Coll. Welch, No. 2203. Det. Evans. (DP.)

Cladonia uncialis (L.) Weber f. *obusata* (Ach.) Wainio—Warren County. Coll. C. C. Deam, No. 50637. Det. C. C. Plitt.

Cladonia verticillata Hoffm. var. *evoluta* Th. Fr.—a.—On ground in woods 4 miles southeast of Corydon, Harrison County. Coll. C. C. Deam, No. 18695. Det. Evans. (DP.) b.—On soil, Bloomington Waterworks Lake, northeast of Bloomington, Monroe County. Coll. Welch, No. 1923. Det. Evans. (DP.) c.—Open grassy land, head of Bloomington Waterworks Lake, Monroe County. Coll. Welch, No. 2206. Det. Evans. (DP.) d.—Head of Waterworks Lake, Griffy Creek, northeast of Bloomington, Monroe County. Coll. Welch, Nos. 7429 and 7430. Det. Welch; Herre. (DP.) e.—In an old fallow field, 1 and ½ miles southeast of Fairview, Switzerland County. Coll. C. C. Deam, No. 58144. Det. Herre. (DP.)

Cladonia verticillata f. *phyllocephala* (Flotow) Wainio—Jefferson County. Coll. C. C. Deam, No. 53410A. Det. Plitt.

Acarosporaceae

Thelocarpon prasinellum Nyl.—On a board, Sayre's Woods, Union County. Fink.

Acarospora cervina (Ach.) Mass.—On granite boulders, Montgomery County. Fink.

Pertusariaceae

Pertusaria pustulata (Ach.) Duby—On apple trees, Sayre's Woods, Union County. Fink.

Lecanoraceae

Lecanora dispersa (Pers.) Röhling—On boulders, Franklin, Montgomery, and Union Counties. Fink.

Lecanora hageni Ach.—On fences, stumps, and limestone, Monroe, Montgomery, and Union Counties. Fink.

Lecanora subfusca (L.) Ach.—On trunk of elm tree, 1012 South College Street, Greencastle, Putnam County. Welch. Coll., No. 7840. Not typical, like California or Austrian material, but agreeing with other specimens from the Midwest. Perhaps condition of plants due to effects of soft-coal or fuel-oil smoke. (DP.)

Lecanora varia (Hoffm.) Ach.—On trees, stumps, and fences, Hendricks, Montgomery, and Union Counties. Fink.

Candelariella aurella (Hoffm.) A. Zahlbr.—On rocks, Montgomery and Union Counties. Fink, listed as *Placodium aurellum.*

Parmeliaceae

Candelaria concolor (Dickson) Arnold—On a tree, along Ohio River, 9 miles west of Mt. Vernon, Posey County. Coll. Clark Nattkemper, May 11, 1935. Det. Torrey. (DP.)

Parmeliopsis diffusa (Weber) Kiddle—On a fallen tree, by Walnut Creek, 5 miles west of Greencastle, Putnam County. Coll. Clark Nattkemper, No. 13, March 19, 1936. Det. Herre. (DP.)

Parmelia borreri Turner—a.—At base of honey locust tree, Cedar Cliff, near Harrodsburg, Monroe County. Coll. Welch, No. 1918. Det. Herre. (DP.) b.—On bark of sugar maple, Greencastle, Putnam County. Coll. Desiah Hamilton, March 25, 1908. Det. Herre. (DP.) c.—Union County. Collected by Fink and Fuson. Determined by E. C. Berry.

Parmelia caperata (L.) Ach.—a.—Brown County. Coll. C. C. Deam, No. 58361. Det. Torrey. (DP.) b.—On sandstone in Bear Creek Canyon, south of Fountain, Fountain County. Col. C. C. Deam, No. 22252. Det. E. C. Berry. c.—Fountain County. Coll. C. C. Deam, No. 22542. Det. C. C. Plitt. d.—On tree trunk, in woods one-half mile north of Vernon, Jennings County, along North Fork of Muscatatuck River. Coll. Welch, No. 7447. Det. Herre. (DP.) e.—On fallen tree, east of Vernon, Jennings County, along North Fork of Muscatatuck River. Coll. Welch, No. 7459. Det. Herre. (DP.) f.—In Beanblossom Woods, near Bloomington, Monroe County. Coll. Welch, No. 1926. Det. Welch. Checked, Herre. (DP.) g.—On honey locust, Cedar Cliff, near Harrodsburg, Monroe County. Coll. Welch, No. 1919. Det. Herre. (DP.) h.—Fern, Putnam County. Coll. and det. L. M. Underwood, April 1893. Checked, Herre. (DP.) i.—On rail fence, Greencastle, Putnam County. Coll. Desiah Hamilton. Det. Herre. (DP.)

Parmelia centrifuga (L.) Ach.—In woods, 6 miles north of Bloomington, on Bean Blossom Creek, northwest of Griffy Creek bridge, Monroe County. Coll. Welch, No. 1927. Det. Herre. (DP.)

Parmelia cetrata Ach.—On cork elm, 13 miles east of Boonville, Warrick County. Coll. Clark Nattkemper, May 12, 1935. Det. Herre. (DP.)

Parmelia conspersa (Ehrh.) Ach.—a.—On sandstone along Little Blue River, near old Canes Mill, about 2 miles south of Grantsburg, Crawford County. Coll. C. C. Deam, No. 46740. Det. E. C. Berry. b.—On granite boulders, in Crawford's Woods, Montgomery County. Fink.

Parmelia conspersa f. *imbricata* Mass.—Crawford County. Coll. Deam, No. 51607, pro parte. Det. Plitt.

Parmelia perforata (Wulf.) Ach.—On cork elm, 13 miles east of Boonville, Warrick County. Coll. Clark Nattkemper, May 12, 1935. Det. Herre. (DP.)

Parmelia perlata (L.) Ach.—On a tree, 13 miles east of Boonville, Warrick County. Coll. Clark Nattkemper, May 12, 1935. Det. Torrey. (DP.)

Parmelia physodes (L.) Ach.—"Indiana." Engelmann Coll., 1827; specimen in Missouri Botanical Garden. Det. E. C. Berry.

Parmelia quercina (Willd.) Wainio—a.—On dead tree branch, east of Vernon, Jennings County, along Muscatatuck River. Coll. Welch, No. 7462. Det. Herre. (DP.) b.—On fallen tree, by Walnut Creek, 5 miles west of Greencastle, Putnam County. Coll. Clark Nattkemper, March 19, 1936. Det. Torrey. (DP.)

Parmelia rudecta Ach.—a.—On trees, in Franklin, Hendricks, Montgomery, Parke, Tippecanoe, and Union Counties. Fink. b.—1.3 miles east of Frichton, Knox County. Coll. Hubricht, B161. Det. E. C. Berry. c.—On bark of tree, by Walnut Creek, 5 miles west of Greencastle, Putnam County. Coll. Clark Nattkemper, March 19, 1936. Det. Torrey. (DP.) d.—On tree, DePauw University Arboretum, Greencastle, Putnam County. Coll. Clark Nattkemper, 1936. Det. Torrey. (DP.)

Parmelia saxatilis (L.) Ach.—Fern, Putnam County. Coll. and det. L. M. Underwood, April, 1893. Checked, Herre. Usneaceae. (DP.)

Ramalina calicaris (L.) Röhling—Greencastle, Putnam County. Det. Herre. (DP.)

Ramalina fraxinea (L.) Ach.—On fence posts, Union County. Fink.

Ramalina subamplicata (Nyl.) Fink—Fern, Putnam County. Coll. L. M. Underwood, April, 1891. Det. Herre. Distributed by Underwood as *R. calicaris*. (DP.)

Usnea dasypoga (Ach.) Röhling var. *plicata* (L.) Crombie—Beanblossom Woods, northwest of Bloomington, Monroe County, at Griffy Creek Bridge. Coll. Welch, No. 1931. Det. Herre. (DP.)

Usnea florida (L.) Weber—a.—Lake Maxinkuckee, Marshall County. Coll. L. M. Underwood, Oct. 8, 1893. Det. Herre. (DP.) b.—Salt Creek Swamp, 12 miles southeast of Bloomington, Monroe County. Coll. Welch, No. 1914. Det. Herre. (DP.)

Caloplacaceae

Caloplaca flavovirescens Arnold: Wulf.—On rocks, "Indiana." Fink in Lichen Flora.

Caloplaca microphyllina (Tuck.) Hasse—On fences, Montgomery and Union Counties. Fink.

Caloplaca oxfordensis Fink: Hedrick—First falls around bend opposite the cascades, north of Bloomington, Monroe County. Coll. Welch, No. 1930. Det. Herre. (DP.) A notable find, as it has hitherto been known only from the type locality at Oxford, Ohio.

Caloplaca pyracea (Ach.) Th. Fries—On dead roots, Montgomery County. Fink.

Caloplaca sideritis (Tuck.) A. Zahlbr.—On limestone boulders, Franklin, Montgomery, and Putnam Counties. Fink.

Caloplaca ulmorum Fink—On trees, Tippecanoe County. Fink.

Caloplaca variabilis (Pers.) Müll. Arg.—On exposed limestone boulder, Franklin County. Fink.

Teloschistaceae

Xanthoria candelaria (L.) Kickx.—On maples, Montgomery County. Fink, as *Teloschistes lychneus.*

Xanthoria candelaria var. *laciniosa* (Duf.) Arnold—On tree trunk in pasture, south of Vandalia railroad station, near Greencastle, Putnam County. Coll. Welch, No. 1929. Det. Herre. Spores 5-7 by 11-16 μ. (DP.)

Xanthoria parietina (L.) Beltr.—On tree trunk in pasture, south of Vandalia railroad station, near Greencastle, Putnam County. Coll. Welch, No. 1929 and No. 7565. Det. Herre. (DP.)

Buelliaceae

Buellia punctata (Hoffm.) Mass.—On board fences and telephone poles, Franklin, Montgomery, and Union Counties. Fink, as *Buellia myriocarpa.*

Rinodina ocellata (Hoffm.) Arnold—On rocks in Crawford's Woods, Montgomery County. Fink, as *Rinodina lecanorina.*

Physciaceae

Pyxine sorediata (Ach.) E. Fries—On old logs along creek, Montgomery County. Fink.

Physcia clementiana (Ach.) Kickx.—a.—On walnut trees, Franklin and Montgomery Counties. Det. Fink. b.—On rock, near Bloomington, Monroe County. Det. Herre. (DP.)

Physcia endochrysea (Hampe) Nyl.—On trees and rocks, Franklin, Monroe, and Montgomery Counties. Fink.

Physcia leucoleiptes (Tuck.) Lettau—On trees, Franklin, Monroe, and Montgomery Counties. Fink.

Physcia obscura (Ehrh.) Hampe—On trees, Franklin, Montgomery, and Union Counties. Fink.

Physcia pulverulenta (Schreber) Nyl.—a.—On trees, stumps, and fences, Franklin, Montgomery, and Union Counties. Fink.

Physcia setosa (Ach.) Nyl.—On a tree trunk, east of Vernon, along Muscatatuck River, Jennings County. Coll. Welch, No. 7461. Det. Herre. (DP.)

Physcia stellaris (L.) Nyl.—On a tree trunk, near Bloomington, Monroe County. Coll. Welch, No. 7432. Det. Herre. (DP.)

Physcia tribacia (Ach.) Nyl.—a.—On old posts and on trees, especially near base of trunk, Hendricks, Montgomery, Parke, and Union Counties. Fink. b.—On a tree trunk, near Bloomington, Monroe County. Coll. Welch, No. 7433. Det. Herre. (DP.)

Physcia virella (Ach.) Flagey—a.—Running over mosses on limestone cliffs, one-half mile north of Vernon, along North Fork of Muscatatuck River, Jennings County. Coll. Welch, Nos. 7435, 7437, and 7442. All det. Herre. (DP.) b.—On trunk of ash tree, in pasture south of Greencastle, Putnam County. Coll. Welch, No. 7841. Det. Herre. (DP.)

Anaptychia fusca (Hudson) Wainio—On trees, Montgomery County. Fink, as *Physcia aquila.*

Studies in Indiana Bryophytes VI

WINONA H. WELCH, DePauw University

The mosses used in this study are Indiana collections in herbaria in the following institutions: Indiana University, Butler University, DePauw University, University of Illinois, Earlham College, Field Museum of Natural History, and the New York Botanical Garden.

The nomenclature is that of A. J. Grout, The Moss Flora of North America North of Mexico 2:242-260. 1935.

The asterisk preceding the name of a county indicates that the species has been recorded from that locality but has not been studied by the author. The asterisk following the name of a species indicates that this is the first known published record for Indiana.

The recorded range of each species has been extended by the author's collections which were made with the financial assistance of an Indiana Academy of Science research grant through the American Association for the Advancement of Science and by the aid of a research grant from the Graduate Council of DePauw University.

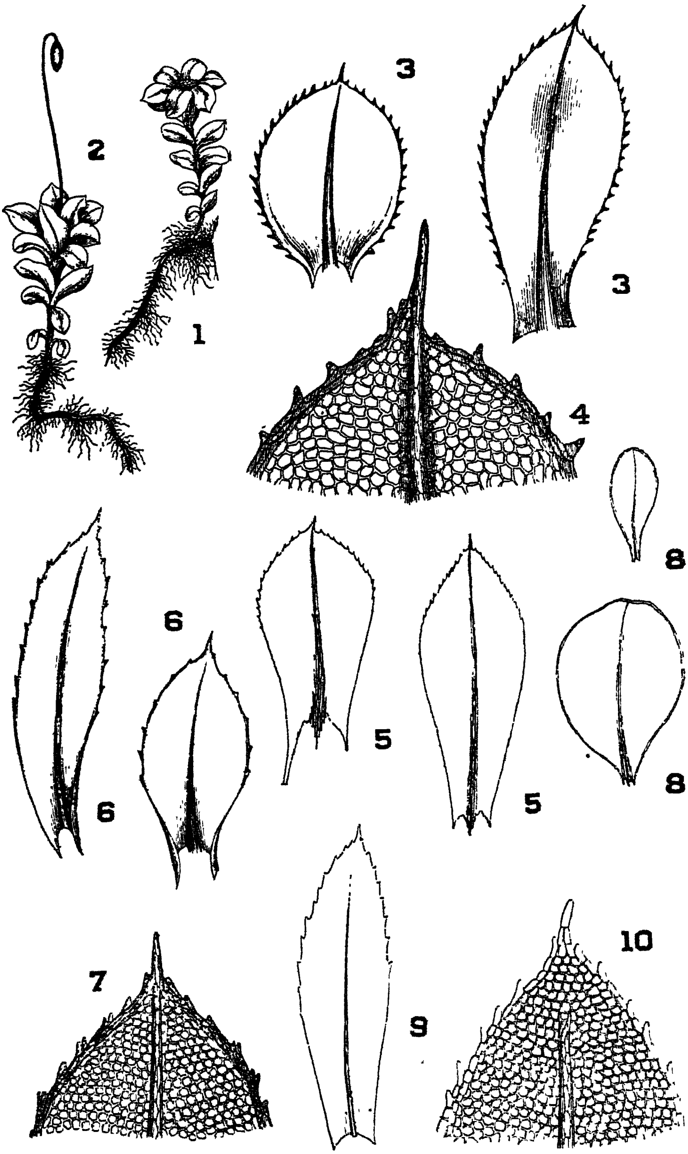
Mniaceae

Plants conspicuous, commonly in mats or tufts; stems often with clusters of brown radicles; leaves of various shapes, the median usually distinct and somewhat loosely arranged, the terminal frequently in a rosette, some with border of elongated cells, margins entire or serrate with single or double teeth, strongly costate to or nearly to the apex; inflorescence terminal, dioecious or synoecious; sporophytes single or several from one perichaetium; seta elongated; capsules horizontal to pendulous; peristome double, teeth of outer peristome 16.

Mnium is the only genus of this family known to occur in Indiana. A key based upon vegetative characteristics is presented although several species of Mnium can not be determined accurately without the antheridia, archegonia, and sporophytes.

Dr. A. LeRoy Andrews (*in litt.*) has advised me that *M. medium* should be found in the state but *M. rostratum* is a common species in states south of Indiana; that *M. medium* is hardly identifiable by its leaves with any degree of certainty and can be distinguished from *M. affine* only by its synoecious inflorescence and its greater tendency to have grouped sporophytes; that *M. rostratum* is also difficult to determine by its leaves and without the distinct sporophytes; and that most or all of the sterile material called *M. rostratum* in the northern states is *M. affine* or some other species.

No sporophytes were found on plants which were identified as *M. medium* or *M. rostratum*. Many of the vegetative characteristics of plants resembling *M. medium* agree with *M. affine* and some of the leaf



All figures are taken, with permission, from A. J. Grout, Mosses with Hand-lens and Microscope (M.H.M.).

Mnium affine (M.H.M., pl. 49). Fig. 1. Male gametophyte, enlarged. Fig. 2. Female gametophyte and sporophyte, enlarged. Fig. 3. Cauline leaves, enlarged. Fig. 4. Upper portion of leaf, enlarged. *Mnium cuspidatum* (M.H.M. Fig. 117 e). Fig. 5. Cauline leaves, x 10. *Mnium marginatum* (M.H.M., pl. 51). Fig. 6. Cauline leaves, enlarged. Fig. 7. Upper portion of leaf, enlarged. *Mnium punctatum* (M.H.M. Fig. 118 c, e). Fig. 8. Cauline leaves, x 4. *Mnium stellare* (M.H.M. Fig. 121). Fig. 9. Cauline leaf, enlarged. Fig. 10. Upper portion of leaf enlarged.

characters of plants which one might determine as *M. rostratum* apply to the forms of *M. affine* in which the teeth are reduced or almost entirely lacking. In the absence of material possessing inflorescences and sporophytes it has seemed advisable to exclude *M. medium* and *M. rostratum* from the Indiana species of Mniaceae.

Mnium

1. Leaves with a border of elongated cells . . . . . 2.
   Leaves without a conspicuous border of elongated cells, serrate above, cells isodiametric, costa ending below apex . . *stellare*.
2. Margins of leaves entire . . . . . *punctatum*.
   Margins of leaves serrate . . . . . 3.
3. Teeth in pairs . . . . . *marginatum*.
   Teeth single . . . . . 4.
4. Margins serrate in upper ½ to ⅔ only . . . . *cuspidatum*.
   Margins serrate nearly to base . . . . *affine*.

M. affine Bland. (Fig. 1-4.) Leaves spreading, crispate or irregularly distorted when dry, oval to obovate, short cuspidate, sometimes slightly decurrent, bordered with 2-4 rows of narrow cells, commonly toothed from apex to base with sharp teeth of 1-3 cells each but the teeth in some forms much reduced or almost entirely lacking; costa percurrent, ending in cuspidate apex; leaf cells subhexagonal, slightly elongated in oblique direction from costa to border and arranged in rows, up to 50μ in longest diameter, gradually decreasing in size from costa to border; dioecious, sporophytes usually single, present in spring. On moist, shaded rock, soil, logs, stumps, and tree trunks in Carroll, Clark, Delaware, Dubois, Floyd, Fountain, Gibson, Hamilton, Harrison, Jasper, Jefferson, Lake, LaPorte, Lawrence, Madison, Marshall, Martin, Monroe, Montgomery, Morgan, Noble, Owen, Parke, Perry, Porter, Putnam, Randolph, Ripley, St. Joseph, Spencer, Steuben, Warren, Washington, Wayne, and Wells counties.

M. cuspidatum (L.) Leyss. (Fig. 5). Leaves spreading, much crisped and distorted when dry, obovate, acute to short acuminate, base narrow and decurrent, bordered with 2-4 rows of narrow cells, serrate in upper ½ or ⅔ only, teeth single, acute, 1-celled; costa percurrent; leaf cells irregularly rounded-hexagonal, up to 25μ in diameter; synoecious; sporophytes single, present in spring. On moist, shaded soil, logs, rock, tree trunks, and stumps in Allen, *Brown, Carroll, Cass, Clark, Crawford, Decatur, Delaware, Dubois, Elkhart, Floyd, Fountain, Grant, *Hamilton, Harrison, Henry, Huntington, Jasper, Jefferson, Jennings, Knox, Kosciusko, Lagrange, Lake, LaPorte, Lawrence, Madison, Marion, Marshall, Martin, Monroe, Montgomery, Noble, Orange, Owen, Parke, Perry, Pike, Porter, Posey, Pulaski, Putnam, *Randolph, Ripley, Saint Joseph, Scott, Starke, Steuben, Sullivan, Warren, Washington, Wayne, Wells, and White counties.

Mnium marginatum (Dicks.) Pal. de Beauv. (Figs. 6-7.) Leaves erect-spreading, rather distant and few, not forming a conspicuous rosette at end of stem, much crisped and twisted when dry, oblong to ovate, short acuminate, decurrent, bordered throughout with narrow, reddish cells, serrate, teeth short and in pairs; costa reddish, not toothed dorsally, frequently percurrent and joining border to form an apiculus; leaf cells subquadrate and somewhat uniform in size, except at base where much elongated, in longitudinal rows, up to 35μ in diameter; synoecious; sporophytes single, present in spring. On moist rock and soil in woods in Jefferson, Madison, Parke, Porter, and Putnam counties.

Mnium punctatum Hedw. (Fig. 8.) Leaves spreading, usually slightly wrinkled and distorted when dry, oval to obovate-spatulate, broadly rounded to slightly emarginate at apex, gradually narrowing at base, not decurrent or slightly so, border distinct, sometimes reddish, entire; costa ending below apex or percurrent, occasionally forming with the border a short blunt point at apex; leaf cells subhexagonal to subrhomboidal, frequently elongated and in oblique rows from costa to border, up to 150μ in longest diameter; commonly dioecious but occasionally synoecious; sporophytes generally single, present in winter or spring. On moist, shaded rock, logs, and soil in Cass, Dubois, Montgomery, Owen, Parke, Porter, Putnam, and Steuben counties.

Mnium stellare Reich.* (Figs. 9-10). Leaves erect-spreading, slightly undulate or irregularly curved when dry, elliptic to ovate, decurrent, apex obtuse to acute, usually not bordered with narrow cells, upper leaves serrate above with broad 1-celled teeth; costa reddish, abruptly ending some distance below the apex; leaf cells rounded to hexagonal, almost isodiametric, up to 30μ in diameter; dioecious; sporophytes single, present in spring and summer. Putnam County. (Welch *7844*, June 3, 1936, base of dead tree trunk, bank of Mill Creek, Hoosier Highlands. DP. Hb.)

Observations on the Presence of Stomata in some Species of Cuscuta

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The evolutionary departure of phanerogamic plants from the way of normal autotrophic living and their development along the pathway leading to the nutritional status known as parasitism commonly involves a number of morphological changes and reductions associated with their new and more dependent way of life. The more noticeable of these changes involve the photosynthetic apparatus together with the development of haustoria which serve to attach the parasite to its host and to extract food from it. Leaves often become smaller. The chlorophyll is commonly reduced or completely lacking.

Comparisons among the large number of parasitic and saprophytic phanerogams show great differences in the amount of modification which has taken place. In the mistletoes, for example, the leaves and chlorophyll appear to be but slightly if at all reduced. In other plants, such as *Monotropa*, the reduction of the structures associated with the photosynthetic process is apparently complete.

Members of the genus *Cuscuta* are well known parasitic plants in which the leaves have been reduced to insignificant scale-like structures. They are often cited in textbooks as examples of "plants completely parasitic" because of the lack of roots, leaves, chlorophyll, and, consequently, the capacity to photosynthesize. An examination of the literature, however, shows there is, in fact, no agreement of opinion in regard to the amount of chlorophyll present, the presence or absence of stomata, or the ability of the plants to manufacture foods.

Sachs (6) says: "Like the mistletoe, so also are the species of *Cuscuta* parasitic on the aerial green shoots of woody plants: their parasitism is, however, complete, since they not only possess no roots fastening them into the soil, but they also completely lack chlorophyll, and are necessitated to take the whole of their nourishment from the host." Seifriz (7) makes the following statement: "The true parasite lacks chlorophyll and must therefore obtain all its nourishment from the host. One of the best known is the dodder, *Cuscuta*. It is a typical seed plant but lacks chlorophyll and roots, haustoria taking the place of the roots." Peirce (5) states: "After the comparatively small amount of food stored in their seeds is consumed the Cuscutas are absolutely dependent upon their hosts for food." A number of additional references might be quoted in which the statements are definitely made to the effect that species of *Cuscuta* do lack chlorophyll and thus are unable to photosynthesize.

This opinion, however, is not held by all writers. Strasburger (2), for example, states: "*Cuscuta europaea* may be cited as an example of a

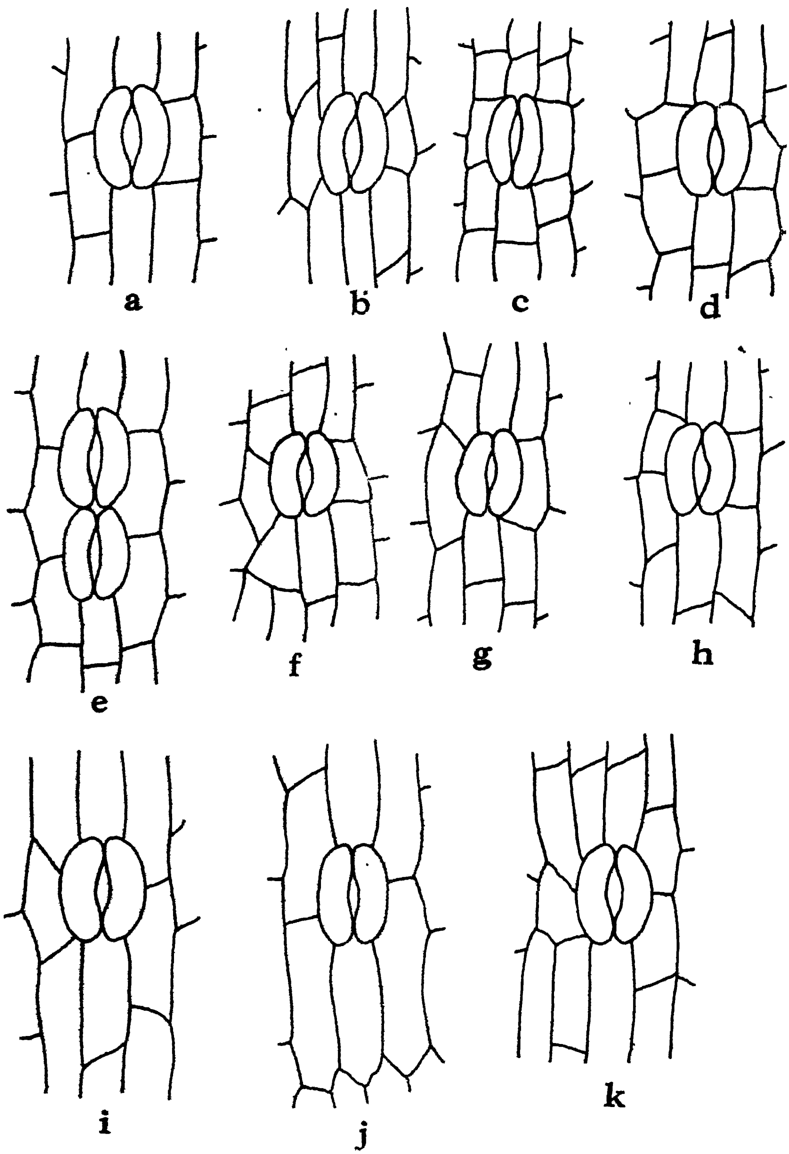
parasitic phanerogam. Although, owing to the possession of chlorophyll, it seems to some extent to resemble normally assimilating plants. . . ." Varrelman (9) says: "Dodder seed germinates and sends forth a green (protonema-like) filament. Its buds also are quite green, its fruits very green. Alcoholic and ether extracts would show that the fruits have as much chlorophyll as any other convolvulaceous plant, its buds nearly as much, its haustellate areas about half as much and other parts of the stem a little. Inasmuch as plants with little chlorophyll produce more carbohydrate per unit than those with much chlorophyll, it is quite likely that *Cuscuta* may be able to sustain itself on its own organic foods, as does mistletoe. *Cuscuta* and *Cassytha* are green plants, even though they are parasites. They do contain chlorophyll, both alpha and beta."

Observations of different species of *Cuscuta* while living show a great deal of variation with respect to the amount of green color which they display. Some species are unquestionably green to a greater or lesser degree while others show little or no such coloration. It is evident that some species, perhaps the majority, do develop chlorophyll to some extent and consequently have the capacity to produce a part, at least, of their required food.

Kotschyev (3) states: "The pale green *Cuscuta Cephalanthi* and *Cuscuta europaea* liberate a small amount of oxygen in the light." This indicates that photosynthesis occurs in these species. Several species contain more green pigment than do these two and probably photosynthesize to a still greater extent. As far as is known the degree to which the various species of *Cuscuta* carry on photosynthesis has not been satisfactorily investigated by physiologists.

A great difference of opinion also exists relative to the presence or absence of stomata on the stems of *Cuscuta*. These structures are essential for the exchange of gases during the photosynthetic and respiratory processes and thus are intimately related to the question of photosynthesis.

Thomson (8) says: "The plant (*C. reflexa*) bears no leaves; its outer surface is covered by a distinct, though thin, cuticle; neither this species nor any other species of the Cuscutaceae is possessed of stomata," and "The presence of an uninterrupted cuticle over all its surface exposed to the air, and the total absence of stomata, render it extremely difficult for what chlorophyll there is in its tissues to obtain the necessary carbon dioxide for the photosynthesis of carbohydrate." Peirce (5) states of *C. americana*: "The epidermis, seldom if ever interrupted by stomata. . . ." DeBary (1) says: "in the stems of *Cuscuta* there is one stoma to many hundred epidermal cells." Mirande (4) in his excellent and comprehensive paper on the physiology and anatomy of *Cuscuta* states that in all of the large species the stomata form an important aerating apparatus. He found them on all parts of the stem but with the greatest abundance in the vicinity of the nodes, flowers, and floral axes. His report was limited almost entirely to those species having very large stems now included in the subgenus Monogyna. He found stomata abundant in *C. japonica* and *C. exaltata*, less abundant in *C. monogyna* and *C. Lehmanniana* and somewhat less yet in *C. lupuliformis*. He illustrates with camera lucida



Sketches illustrating stomata found on stems of species of Cuscuta. All enlarged approximately 400x.

a—C. reflexa; b—C. Lehmanniana; c—C. lupiliformis; d—C. japonica; e—C. monogyna; f—C. compacta; g—C. jalapensis; h—C. americana; i—C. campestris; j—C. Gronovii; k—C. Polygonorum.

sketches those which he found on *C. japonica* and also one on *C. chinensis*, a smaller stemmed species.

No positive statement has been found in the literature relative to the presence of stomata on any American species with the exception of the one made by Peirce that on *C. americana* they are seldom if ever present. Last autumn (1942) seeds of three Indiana species common in Putnam County (*C. campestris* Yuncker, *C. Gronovii* Willdenow, *C. Polygonorum* Engelmann) were collected. They were planted in the greenhouse where they grew well on a variety of hosts and flowered. When matured, the stems were examined for stomata which were found to be present in each of the species.

Although they are infrequent, inconspicuous, and easily overlooked, there is at least one stoma to each several hundred epidermal cells. The shape and arrangement of the stomata found in these three species agree with Mirande's description of those of the larger stemmed species. They are rounded-oval with their long axis parallel with that of the stem. Neither the guard cells nor the surrounding cells showed any concentration of color nor was there any noticeable elevation at the site of the stomata, as is characteristic of some of the other species. They were not found to be more numerous in the vicinity of the nodes, haustoria, inflorescences, or floral parts. In *C. Polygonorum* (originally named *C. chlorocarpa* by Engelmann) the developing capsule is often definitely green. One would suspect, therefore, that stomata might be present on the fruit, but none were found.

The stems of herbarium specimens of several species were examined for stomata after having been softened by boiling. This method, however, did not prove very successful. With the exception of species with comparatively large stems, it was impossible to properly prepare the epidermis for microscopical examination. Stomata have been found, however, in every species in which it has been possible to make a proper examination of the material available. It is believed that they are probably present on the stems of all species.

The following list includes, in addition to the three living species already discussed, those in which it was possible to prepare herbarium material for examination.

Cuscuta reflexa Roxburgh (*fig. a*). It is difficult to understand why Thomson did not find stomata on the stems of this common Asiatic species. They are not as abundant or as conspicuous as are those on some of the other species. However, they were present on all of the stems examined and usually situated on slight papillate elevations of the epidermis. Only dry herbarium material was available for study and it is possible that they are less conspicuous on living stems, though the contrary would seem more probable.

Cuscuta Lehmanniana Bunge (*fig. b*). Stomata were more numerous in this species than in any of the others examined. Mirande found them to be less abundant in this species than with *C. japonica* and *C. exaltata* but I found the contrary to be true. About 50 were counted in a centimeter of stem length. They are very easily observed because the stomatal

area is strongly reddened and slightly dome-shaped with the stomata at the tops of the elevations.

Cuscuta lupuliformis Krocker (*fig. c*). The stomata are situated on low, reddish, papillate elevations. Twenty to 30 were counted in one centimeter of the stem but in the vicinity of haustoria as many as 50 were found in a comparable area.

Cuscuta japonica Choisy (*fig. d*). Mirande found stomata more abundant on stems of this species than any other. In the herbarium material examined I found up to 25 in a centimeter of stem length with a somewhat greater number in the haustorial areas. The stomata are situated on slightly raised and reddened areas which renders them conspicuous and easily seen.

Cuscuta monogyna Vahl (*fig. e*). In the several specimens examined of this species the stomata were very conspicuous because the guard cells exhibited a bright yellow pigment which was in strong contrast with the adjacent non-pigmented cells. Whether this yellow pigment is characteristic and present in living material is not known. The number of stomata varied considerably with usually 5 to 15 present in a centimeter of stem length. Two stomata were seen adjacent to each other, a condition observed only this once.

Cuscuta exaltata Engelmann. The stomata in this species, which were found to be fewer than for *C. Lehmanniana*, are located on slight elevations, the cells of which exhibit a brown color.

Cuscuta compacta Jussieu (*fig. f*). A few pieces of stem of this American species were examined. The stomata were found to be present though infrequent and inconspicuous. Living material might reveal them to be more abundant.

Cuscuta jalapensis Schlechtendal (*fig. g*). In this Mexican species a small number of scattered stomata on slightly raised areas were found.

Cuscuta americana Linnaeus (*fig. h*). Peirce stated that this species had few if any stomata. The writer found them to be present though infrequent, inconspicuous and indistinct.

Cuscuta campestris Yuncker (*fig. i*), *C. Gronovii* Willdenow (*fig. j*), and *C. Polygonorum* Engelmann (*fig. k*) are discussed above.

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Indiana Plant Distribution Records, IV. 1943

This is a continuation of the series of annual reports of new distribution records intended to keep Deam's "Flora of Indiana" up to date. The report is given in three sections, viz. "SPECIES," giving new county records with the location of confirming specimens; "NOMENCLATORIAL CHANGES" in which an attempt is made, within the limits and in the spirit of conservative tavonomy, to keep the "Flora" up to date in plant names; a "DELETIONS" in which known previous errors are corrected.

SPECIES

Genera are listed in the order used in the "Flora" and species are given in alphabetical order within the genera. Symbols following the counties indicate the herbaria where specimens have been deposited. Species, varieties or forms new for the state are given in bold face type and these together with name changes are followed by literature references. Cases of doubt whether the species will become a part of the state flora are preceded by an asterisk.

The specimens listed have been collected by the following collectors:—Butler University (B): Charles C. Deam, Charles M. Ek, W. J. Emerson, Ray C. Friesner, Scott McCoy and J. E. Potzger; Deam Herbarium (D): Charles C. Deam, W. J. Emerson and Ray C. Friesner; DePauw University (DP): Winona H. Welch; Franklin College (Fr): Naomi Mullendore; Gray Herbarium (G): Charles C. Deam; Huntington College (Hu): Fred A. Loew; Indiana University (IU): Ruth M. Baker, Mary Everly, Bette Lutes and LaVerne Schachtsiek; U. S. National Herbarium (N); J. T. Scovell and B. W. Evermann.

Other symbols used are: (F) Field Museum, (Ċ) University of California, (Go) Goshen College, (W) Wisconsin.

The committee maintains a card file showing published distribution of each species within the state. Botanical workers needing such information may obtain distribution maps of any species recorded in the "Flora" or subsequently added in these reports by requesting same from the secretary of this committee.

Botrychium dissectum var. *obliquum*, Hendricks (B). *Onoclea sensibilis*, Huntington (Hu). *Asplenium platyneuron*, Elkhart (B). *Equisetum arvense*, Carroll (B). *Selaginella rupestris*, Lagrange (D,B). *Typha angustifolia*, Rush (B). *Potamogeton gramineus* var. **myriophyllus** Robbins, Porter (F). Rhodora 45: 150. 1943. *P. g.* var. **typicus** Ogden, Lake (C, F, G, N), Marshall (N) Rhodora 45: 145. 1943. **P. gramineus X illinoensis** Ogden, Fulton (G), Kosciusko (N), Marshall (N), Steuben (G). Rhodora 45: 188. 1943. *P. nodosus* Poir. (*P. americanus*), Pulaski (DP). *Anacharis canadensis*, Hendricks (B).

Festuca elatior, Rush (B), Shelby (B). *F. obtusa*, Rush (B). *Bromus commutatus*, Carroll (B), Clinton (B), Hamilton (B), Rush (B), Shelby (B). *B. inermis*, Hamilton (B), Madison (B). *B. japonicus*, Hamilton (B), Madison (B), Owen (B). *B. latiglumis*, Hendricks (B). *B. secalinus*, Hamilton (B), Rush (B), Shelby (B). *B. tectorum*, Clinton (B), Hamilton (B), Jennings (B), Madison (B), Shelby (B). *Glyceria striata*, Rush (B). *Poa annua*, Tipton (B). *P. compressa*, Owen (B), Rush (B), Shelby (B), *P. pratensis*, Carroll (B), Rush (B), Shelby (B). *P. sylvestris*, Shelby (B), Rush (B), Tipton (B).

Eragrostis cilianensis, Rush (B). *E. frankii*, Boone (B), Rush (B). *E. hypnoides*, Boone (B). *E. pectinacea*, Rush (B). *E. spectabilis*, Boone (B), Hendricks (B). *Diarrhena americana*, Marion (B). *Dactylis glomerata*, Hamilton (B), Shelby (B), Tipton (B). *Triodia flava*, Boone (B), Fayette (B), Rush (B). *Agropyron smithii*, Morgan (B), Shelby (B). *Elymus villosus* f. *arkansanus*, Boone (B). *Hordeum jubatum*, Shelby (B). *Sphenopholis intermedia*, Rush (B). *Alopercurus carolinianus*, Carroll (B), Monroe (IU). *Agrostis alba*, Bartholomew (B). *A. hiemalis*, Madison (B), Shelby (B). *A. perennans*, Hendricks (B), Rush (B). *Cinna arundinacea*, Boone (B), Hendricks (B). *Phleum pratense*, Rush (B), Shelby (B), Tipton (B). *Muhlenbergia frondosa* (Poir.) Fern. (*M. mexicana* of Flora) Rhodora 45: 235. 1943. Shelby (B). *M. f.* forma *commutata*, Kosciusko (IU). *M. schreberi*, Rush (B), Shelby (B). M. *tenuiflora*, Hendricks (B). *Sporobolus asper*, Hendricks (B), Rush (B). *S. neglectus*, Boone (B), Hendricks (B), Marion (B), Rush (B). S. *vaginaeflorus*, Boone (B), Hendricks (B), Rush (B).

Brachyelytrum erectum, Marion (B). *Aristida oligantha*, Boone (B). A. *purpurascens*, Kosciusko (IU). *Spartina pectinata*, Morgan (B). *Eleusine indica*, Huntington (Hu). *Phalaris arundinacea*, Carroll (B), Hamilton (B). *Leersia oryzoides*, Shelby (B). *Digitaria ischaemum*, Hendricks (B), Kosciusko (IU), Rush (B). *D. sanguinalis*, Rush (B), Shelby (B). *Leptoloma cognatum*, Boone (B). *Panicum capillare*, Hendricks (B). *P. commutatum*, Bartholomew (B). *P. dichotomiflorum*, Boone (B), Fayette (B), Hendricks (B), Rush (B), Shelby (B). *P. gattingeri*, Boone (B), Fayette (B), Rush (B), Shelby (B). *P. latifolium*, Bartholomew (B). *P. lindheimeri*, Cass (D), Steuben (B, D). *P. linearifolium*, Morgan (B). *P. l.* var. *werneri*, Morgan (B). *P. philadelphicum*, Boone (B). *P. virgatum*, Hendricks (B). *Echinochloa crusgalli*, Rush (B), Shelby (B). *Setaria italica*, Fayette (B). *S. lutescens*, Fayette (B), Putnam (B), Rush (B). *S. viridis*, Rush (B). *Andropogon gerardi* Vitman (A. furcatus of Flora) Rhodora 45: 258. 1943. Hendricks (B), Marion (B). *A. scoparius*, Hendricks (B), Marion (B). *Sorghum halepense*, Putnam (B), Rush (B). *Sorghastrum nutans*, Hendricks (B).

Cyperus filiculmis, Madison (B). *C. schweinitzii*, Howard (B), Starke (B). *Scirpus smithii* f. *setosus* Fern. Rhodora 44: 479. 1942. Steuben (D). *Eleocharis calva*, Clinton (B), Elkhart (B), Hendricks (B). *E. intermedia*, Miami (B). *E. olivacea*, Elkhart (B). *E. smallii*, Howard (B).

Carex albursina, Jennings (B). *C. amphibola*, Jennings (B). *C. bebbii*, Tippecanoe (B). *C. brevior*, Hancock (B), Jackson (B), Jennings (B), Marion (B). *C. bushii*, Jennings (B). *C. cephalophora*, Hendricks (B). *C. conjuncta*, Jennings (B), Marion (B). *C. convoluta*, Marion (B). *C. cristatella*, Cass (B), Tipton (B). *C. davisii*, Hancock (B). *C. debilis*, Jennings (B). *C. festucacea*, Hendricks (B), Jennings (B), Marion (B). *C. granularis*, Jackson (B), Tippecanoe (B). *C. gravida* var. *lunelliana*, Tippecanoe (B). *C. grayii*, segregation of the variety *hispidula* leaves the following counties for the species: Adams (D), Carroll (B, D), Cass (D), Clinton (D), Delaware (D), Elkhart (D), Gibson (D), Grant (D), Howard (B, D), Kosciusko (D), Lagrange (B, D), Marion (D), Marshall (D, W), Miami (D), Montgomery (D, W), Newton (DP), Noble (D), Putnam (DP), Rush (D), St. Joseph (D), Steuben (D), Tippecanoe (D), Wabash (D), Wells (D), White (D), Whitley (D). *C. g.* var. *hispidula*, Allen (D), Bartholomew (D), Blackford (D), Clay (D), Daviess (D), DeKalb (D), Dubois (D), Fayette (D), Fountain (D, W), Grant (B), Greene (D), Hamilton (D), Hancock (D), Hendricks (D), Henry (D), Howard (B), Huntington (D), Jackson (B, D), Jay (D), Lawrence (D), Marion (B), Miami (B), Montgomery (W), Posey (D), Putnam (DP, W), Ripley (D), Scott (D), Shelby (B), Spencer (D), Vanderburgh (D), Warrick (D), Washington (D).

Carex grisea, Hendricks (B). *C. hirtifolia*, Hendricks (B). *C. hirsutella*, Jennings (B). *C. hitchcockiana*, Hancock (B). *C. lacustris*, Clinton (B). *C. lanuginosa*, Jennings (B). *C. lasiocarpa* var. *americana*, Elkhart (B). *C. laxiflora*, Hancock (B), Hendricks (B). *C. leavenworthii*, Jennings (B). *C. normalis*, Clinton (B). *C. oligocarpa*, Hancock (B). *C. prairea*, Elkhart (B). *C. rosea*, Jackson (B). *C. scoparia*, Hamilton (B). *C. sparganioides*, Boone (B), Hancock (B), Jackson (B). *C. stipata*, Jennings (B). *C. swanii*, Jennings (B). *C. tenera*, Elkhart (B), Jackson (B). *C. trichocarpa*, Howard (B). *C. virescens*, Jennings (B).

Arisaema atrorubens, Hendricks (B). *A. a.* f. *viride*, Hendricks (B), Marion (B). *A. a.* f. *zebrina*, Marion (B). *A. dracontium*, Madison (B), Shelby (B). *Commelina communis*, Carroll (B). *Tradescantia subaspera* var. *typica*, Hancock (B). *Juncus canadensis*, Hamilton (B), Putnam (B). *J. dudleyi*, Boone (B). *J. macer*, Boone (B), Hamilton (B). *J torreyi*, Hendricks (B). *Uvularia grandiflora*, Shelby (B). *Allium canadense*, Madison (B), Shelby (B). *A. tricoccum*, Hendricks (B). *Lilium canadense* var. **editorum** Fernald. Rhodora 45: 393-395. 1943. Dearborn (D), Franklin (D). *Erythronium americanum*, Huntington (Hu). **Ornithogalum nutans** L. Gray Man. 7 ed., p. 290. Elkhart (B, D, Go). *Camassia scillioides*, Vigo (N). *Smilacina racemosa* var. *cylindrata*, Rush (B), Shelby (B). *Polygonatum biflorum*, Ohio (B), Ripley (B). *P. canaliculatum*, Carroll (B), De Kalb (B), Hendricks (B), Henry (B), Howard (B), Knox (B), Marion (B), Ohio (B), Owen (B), Parke (B). *Trillium grandiflorum*, Huntington (Hu). *Smilax ecirrhata*, Shelby (B). *S. herbacea*, Carroll (B), Tipton (B). *S. h.* var. *lasioneura*,

Carroll (B). *S. hispida,* Rush (B). *S. rotundifolia,* Rush (B). *Dioscorea villosa,* Rush (B), Tipton (B). *Sisyrinchium albidum,* Jackson (IU). *Spiranthes cernua,* Hendricks (B). *Liparis liliifolia,* Hendricks (B), Marion (B).

Populus deltoides, Hendricks (B). *P. tremuloides,* Huntington (Hu), *Salix cordata,* Boone (B). *S. discolor,* Huntington (Hu). *Juglans cinerea,* Huntington (Hu). *Carya cordiformis,* Tipton (B). *C. laciniosa,* Tipton (B). *Ostrya virginiana,* Huntington (Hu). *O. v.* forma *glandulosa,* Tipton (B). *Fagus grandifolia,* Huntington (Hu.) *Quercus alba,* Hendricks (B). *Q. bicolor,* Huntington (Hu). *Q. borealis* var. *maxima,* Huntington (Hu). *Q. imbricaria,* Blackford (D). *Q. macrocarpa,* Huntington (Hu). *Q. muhlenbergii,* Blackford (D). *Q. palustris,* Huntington (Hu). *Q. velutina,* Huntington (Hu). *Ulmus americana,* Huntington (Hu). *Celtis occidentalis* var. *crassifolia,* Rush (B). *Humulus americanus,* Boone (B). *Cannabis sativa,* Starke (IU). *Urtica procera,* Carroll (B). *Laportea canadensis,* Rush (B). *Pilea pumila,* Hendricks (B). *Boehmeria cylindrica,* Marion (B), Rush (B). *Parietaria pennsylvanica,* Madison (B). *Asarum reflexum,* Rush (B). *Aristolochia serpentaria,* Hamilton (B). *Rumex crispus,* Madison (B). *R. obtusifolius,* Cass (B). *Polygonum aviculare,* Howard (B). *P. convolvulus,* Carroll (B). *P. hydropiper* var. *projectum,* Rush (B). *P. hydropiperoides,* Boone (B). *P. neglectum,* Porter (B). *P. pennsylvanicum* var. *laevigatum,* Hendricks (B), Rush (B). *P. p.* var. *l.* f. *pallescens,* Boone (B). *P. persicaria,* La Porte (B), Rush (B). *P. punctatum,* Hendricks (B). *P. sagittatum,* Marshall (IU). *P. scandens,* Hendricks (B). *P. virginianum,* Hendricks (B).

Chenopodium album, Cass (B), Miami (B). *C. ambrosioides* ssp. *euambrosioides,* Brown (B), Marion (B). *C. berlandieri,* Hamilton (B), Miami (B). *C. gigantospermum,* Starke (D). *C. pratericola,* Jasper (B). *C. standleyanum,* Kosciusko (D). *Cycloloma atriplicifolium,* Fulton (D), Owen (IU). *Atriplex patula* var. *hastata,* Blackford (D). *A. p.* var. *littoralis,* Allen (D), Jay (D), Wells (D), White (D). *Amaranthus blitoides,* Porter (B). *Acnida altissima,* Hendricks (B), Marion (B), Rush (B). *Oxybaphus nyctagineus,* Huntington (Hu). *Mollugo verticillata,* Marion (B), Huntington (Hu), Rush (B). *Arenaria serpyllifolia,* Carroll (B), Madison (B). **Spergularia rubra,* Tippecanoe (B). *Agrostemma githago,* Hamilton (B). *Silene antirrhina,* Carroll (B), Jennings (B), Madison (B), Shelby (B). *S. cserei, Carroll* (B), Morgan (B). *Saponaria officinalis,* Fayette (B), Huntington (Hu).

Cimicifuga racemosa, Bartholomew (B). *Anemone virginiana,* Hendricks (B). *Hepatica acutiloba,* Huntington (Hu). *Clematis pitcheri,* Daviess (N), Vigo (N), Warren (N). Ann. Missouri Bot. Garden 30: 26. 1943. *Ranunculus abortivus,* Tipton (B). *R. septentrionalis,* Elkhart (B). *Thalictrum dasycarpum,* Shelby (B). *T. revolutum,* Madison (B). *Menispermum canadense,* Rush (B), Tipton (B). *Asimina triloba,* Rush (B). *Sassafras albidum* var. *mollis,* Tipton (B). *Lindera benzoin,* Huntington (Hu). *Lepidium campestre,* Carroll (B), Clinton (B),

Hamilton (B). *L. virginicum,* Carroll (B), Clay (B), Hamilton (B), Madison (B), Shelby (B). *Thlaspi arvense,* Carroll (B), Hamilton (B), Tipton (B). *Sisymbrium altissimum,* Hamilton (B). *S. officinale,* Marion (B). *Barbarea vulgaris,* Madison (B), Tipton (B). *Iodanthus pinnatifidus,* Tipton (B). *Rorippa islandica* var. *microcarpa, Carroll* (B). *R. sylvestris,* Carroll (B). *Capsella bursa-pastoris,* Rush (B). *Camelina microcarpa,* Tipton (B). *Descurainia pinnata* var. *brachycarpa,* Tipton (B). *Hesperis matronalis,* Hamilton (B). *Polanisia graveolens,* Hendricks (B), Owen (IU), Rush (B). *Liquidambar stryraciflua,* Rush (B). *Platanus occidentalis,* Noble (D).

Crataegus crus-galli, Boone (B). *Crataegus mollis,* Elkhart (B), Hamilton (B). *Rubus allegheniensis,* Bartholomew (B). *R. flagellaris,* Huntington (Hu). *R. frondosus,* Huntington (Hu). *R. occidentalis,* Huntington (Hu). *Potentilla arguta,* Morgan (B). **P. intermedia** L. Gray Man. 7ed., p. 482. Carroll (B, D), Marion (B, D). *P. monspeliensis,* Madison (B), Rush (B). *P. recta,* Hamilton (B). *Geum laciniatum,* Madison (B), Shelby (B). *G. l.* var. *trichocarpum,* Madison (B), Tipton (B). *Agrimonia pubescens,* Hendricks (B). *Rosa carolina,* Morgan (B). *R. setigera,* Madison (B). *Prunus americana,* Huntington (Hu).

Desmanthus illinoensis, Hendricks (B). *Cercis canadensis,* Tipton (B). *Cassia hebecarpa,* Huntington (Hu). *Gleditsia triacanthos,* Huntington (Hu). *Baptisia leucantha,* Bartholomew (B). *Medicago lupulina,* Carroll (B). *M. sativa,* Carroll (B). *Melilotus alba,* Carroll (B), Madison (B). *M. officinalis,* Clinton (B), Madison (B), Shelby (B). *Trifolium agrarium,* 'Brown (B). *T. hybridum,* Bartholomew (B), Howard (B), Jennings (B), Lawrence (D), Ohio (B), Tippecanoe (D), Tipton (B), Wells (D). *T. h.* var.**elegans** (Savi) Boiss. Rhodora 45: 331. 1943. Carroll (B), Hendricks (B), Marion (B), Wells (D). *Trifolium pratense,* Fayette (B). *Coronilla varia,* Boone (B). *Desmodium bracteosum* var. *longifolium,* Howard (B). *Strophostyles helveola,* Hendricks (B), Rush (B).

Geranium carolinianum, Clinton (B). *G. maculatum,* Huntington (Hu). X *Rhus pulvinata,* Elkhart (B). *Staphylea trifolia,* Elkhart (B). *Phaseolus polystachios,* Posey (D). *P. p.* var. **aquilonius** Fern. Rhodora 44: 418. 1942. Harrison (D). *Oxalis europaea,* Tipton (B). *O. e.* f. *cymosa,* Marion (B), Rush (B). *O. stricta,* Carroll (B), Elkhart (B), Hamilton (B), Rush (B). *Zanthoxylum americanum,* Rush (B). *Polygala verticillata,* Clay (B). *P. v.* var. *sphenostachya,* Kosciusko (IU). *Acalypha rhomboidea,* Hendricks (B). *A. ostryaefolia,* Monroe (IU), Owen (IU). *Euphorbia dentata,* Fayette (B). *E. maculata,* Rush (B). *E. supina,* Hendricks (B), Rush (B).

Evonymus atropurpureus, Rush (B), Tipton (B). *Celastrus scandens,* Kosciusko (IU). *Acer negundo,* Kosciusko (IU). *Impatiens biflora,* Rush (B). *Rhamnus lanceolata,* Jennings (B). *Vitis vulpina,* Huntington (Hu). *Tilia americana,* Huntington (Hu), Tipton (B). *Malva neglecta,* Huntington (Hu), Madison (B). ***Callirhoe involucrata** (T. & G.) Gray, Jackson (IU). Gray Man. 7ed., p. 568. *Sida spinosa,*. Hendricks (B).

Hibiscus trionum, Fayette (B), Huntington (Hu). *Hypericum perforatum,* Clay (B). *H. sphaerocarpum,* Miami (B). *Viola eriocarpa* f. *leiocarpa,* Marion (B). *V. kitaibeliana* var. *rafinesquii,* Floyd (Fr). *Lythrum alatum,* Boone (B). *Ludwigia palustris* var. *americanum,* Marion (B). *Epilobium coloratum,* Rush (B). *Oenothera laciniata.* Owen (IU). *Oe. pycnocarpa,* Rush (B). *Oe. speciosa,* Owen (IU). *Gaura biennis,* Brown (Fr), Greene (IU). *Sanicula canadensis* var. *typica,* Madison (B), Rush (B). *S. gregaria,* Shelby (B). *Osmorrhiza longistylis,* Huntington (Hu), Shelby (B). *Conium maculatum,* Carroll (B). *Pastinaca sativa,* Fayette (B). *Sium suave,* Huntington (Hu). *Daucus carota,* Kosciusko (IU), Rush (B). *Cornus racemosa,* Hamilton (B).

Lysimachia ciliata, Madison (B). *Fraxinus americana,* Huntington (Hu), Rush (B). *F. lanceolata,* Shelby (B). *Gentiana andrewsii,* Huntington (Hu). *Apocynum cannabinum,* Rush (B). *A. c.* var. *pubescens,* Madison (B). *A. sibiricum,* Marion (B). *Asclepias syriaca,* Madison (B), Rush (B). *Cuscuta cephalanthi,* Cass (DP, B), Clinton (DP, B). *C. polygonorum,* Hamilton (DP, B). *Convolvulus sepium* var. *americanum,* Tipton (B). *Ipomopsis rubra,* Jackson (IU). *Lithospermum arvense,* Tipton (B). *Verbena urticaefolia,* Tippecanoe (B). *Hydrophyllum canadense,* Huntington (Hu). *H. macrophyllum,* Rush (B). *H. virginianum,* Huntington (Hu).

Teucrium canadense var. *virginicum,* Rush (B). *Isanthus brachiatus,* Boone (B), Rush (B). *Scutellaria galericulata,* Johnson (Wi), Floyd (D). *S. incana,* Bartholomew (B). *S. lateriflora,* Delaware (D), Franklin (D). *Scutellaria ovata* ssp. **pseudovenosa** Epling. Univ. California Pub. Bot. 20: 56. 1943. Marion (C), Dearborn (B). *S. o.* var. *versicolor* (Nutt.) Fern. Rhodora 44: 432. 1942. Univ. California Pub. Bot. 20: 52. 1942. Delaware (C), Marion (B), Morgan (B), Switzerland (B). *S. parvula,* White (B). *Leonurus cardiaca,* La Porte (B). *Stachys hispida,* Huntington (Hu), Madison (B). *S. palustris* var. *homotrichia,* Newton (B). *Hedeoma pulegioides,* Hendricks (B), Huntington (Hu), Rush (B). *Lycopus rubellus,* Hamilton (B), Rush (B). *L. uniflorus,* Boone (B), Hamilton (B). *Mentha arvensis,* Boone (B). *M. longifolia* var. *mollissima,* Miami (B). *Collinsonia canadensis,* Hendricks (B), Rush (B).

Physalis ambigua, Porter (B). *P. heterophylla,* Fayette (B), Hendricks (B), Marion (B), Rush (B). *P. subglabrata,* Rush (B). *Solanum carolinense,* Rush (B). *S. nigrum,* Brown (B). *Datura stramonium,* Hendricks (B). *Chaenorrhinum minus,* Madison (B), *Chelone glabra* var. *linifolia,* Rush (B). *C. g.* var. *typica,* Kosciusko (IU). *Penstemon canescens,* Hamilton (B). *Gratiola neglecta,* Clay (B). Rush (B). *Leucospora multifida,* Hendricks (B). *Pedicularis lanceolata,* Huntington (Hu). *Lindernia dubia* (L. d. var. major of Flora), Boone (B), Clay (B). *Veronica arvensis,* Tipton (B). *V. officinalis,* Owen (B). *V. peregrina* var. *typica,* Carroll (B), Rush (B), Tipton (B). *Gerardia*

paupercula var. *typica*, Hamilton (B). *G. p.* var. *borealis*, Elkhart (B). *Aureolaria virginica*, Elkhart (B). *Campsis radicans*, Kosciusko (IU). *Epifagus virginiana*, Rush (B). *Plantago rugelii*, Marion (B). *Galium concinnum*, Carroll (B), Rush (B). *G. obtusum*, Rush (B). **G. verum*, White (D, B), Kosciusko (D). *Sambucus canadensis*, Clinton (B), Madison (B). *Viburnum affine*, Huntington (Hu). *V. dentatum* var. *deamii* (Rehd.) Fern. Owen (IU). Rhodora 43: 649. 1941. *V. lentago*, Huntington (Hu). *Triosteum aurantiacum*, Elkhart (B). *Dipsacus sylvester*, Hendricks (B). *Lobelia cardinalis*, Rush (B). *L. inflata*, Hendricks (B). *L. siphilitica*, Rush (B).

Vernonia altissima, Fayette (B). *Eupatorium serotinum*, Hendricks (B), Marion (B), Rush (B). *Liatris spicata*, Bartholomew (B). *Solidago altissima*, Rush (B). *S. caesia*, Hendricks (B), Rush (B). *S. gigantea*, Hendricks (B). *S. g.* var. *leiophylla*, Boone (B), Rush (B). *S. graminifolia* var. *nuttallii*, Hendricks (B). *S. latifolia*, Rush (B). *S. nemoralis*, Hendricks (B), Rush (B). **S. ulmicaesia** Friesner. Butler Univ. Bot. Stud. 6: 82-83. 1943. Elkhart (D, B). *Aster cordifolius*, Rush (B), Huntington (Hu). *A. ericoides* var. *prostratus*, La Porte (B). *A. paniculatus*, La Porte (B). *A. pilosus*, Fayette (B), La Porte (B), Rush (B).

Erigeron annuus, Clinton (B), Madison (B). *E. canadensis*, Boone (B), Fayette (B), Hendricks (B), Marion (B), Rush (B). *Antennaria neodioica*, Elkhart (B), Jennings (B). *Gnaphalium purpureum*, Clay (B). *Ambrosia elatior*, Elkhart (D), Fayette (B), Hendricks (B), Rush (B). *A. trifida*, Boone (B), Clinton (B), Fayette (B), Henricks (B), Rush (B). *Eclipta alba*, Hendricks (B). *Helianthus decapetalus*, Hendricks (B). *H. grosseserratus*, Boone (B), Marion (B). *H. tuberosus*, Hendricks (B), Marion (B). *Actinomeris alternifolia*, Boone (B), Hendricks (B). *Bidens bipinnata*, Boone (B), Hendricks (B), Rush (B). *B. cernua*, Rush (B). *B. vulgata*, Porter (B), Rush (B). *Galinsoga* **parviflora** Cav. Gray Man. 7ed., p. 843. Fayette (B), Huntington (D), Rush (D).

Anthemis cotula, Fayette (B). *Achillea millefolium*, Madison (B). *Matricaria matricarioides*, Marion (IU), Rush (B), Shelby (B, IU), Tipton (B). *Artemisia annua*, Boone (B). *Erechtites hieracifolia*, Rush (B). *Cacalia atriplicifolia*, Marion (B). *Senecio aureus*, Jackson (B). *Arctium minus* f. **laciniatum** Clute. Plant World 12: 135-138. 1909. Parke ( ). *Cirsium discolor*, Boone (B), Fayette (B), Hendricks (B). *Cichorium intybus*, Hendricks (B), Rush (B). **Tragopogon dubius** Scop. Rhodora 45: 414. 1943. (See also Kearney and Peebles Fl. Plt. Arizona, 1023. 1943.) Gibson (D), Lake (G), Marion (B), Porter (G), Wabash (B). *T. pratensis*, Kosciusko (IU). *T. porrifolius*, Madison (B). *Lactuca biennis*, Marion (B). *L. canadensis* var. *integrifolia*, Fayette (B), Rush (B). *L. c.* var. *latifolia*, Boone (B). *L. c.* var. *l. f. villicaulis* Fern. Rhodora 41: 574. 1939. Crawford (D), Washington (D), Wells (D). *L. scariola*, Brown (B). *Prenanthes altissima*, Rush (B).

NOMENCLATORIAL CHANGES

The following changes in names of Indiana plants are considered by the committee to be likely of acceptance by taxonomists generally. Other published changes have recently appeared in the literature but are temporarily withheld from the list awaiting further evidence of their merit and likelihood of general acceptance.

Dryopteris spinulosa var. intermedia (Muhl.) Underw. to
D. intermedia (Muhl.) A. Gray
Broun Index N. A. Ferns 1938.

Potamogeton americanus Cham. & Schlect. to
P. nodosus Poir.
Rhodora 45: 123. 1943.

Potamogeton gramineus var. graminifolius Fries to
P. gramineus L. var. **typicus** Fern.
Rhodora 45: 143. 1943.

Potamogeton lucens L. to
P. illinoensis Morong.
Rhodora 45: 152. 1943.

Potamogeton pusillus var. mucronatus (Fieber) Graebn. to
P. berchtoldi var. **mucronatus** Fieber.
Pot. Böhm. 40, t. iv., fig. 21. 1838.
Fernald: Linear-leaved Potamogetons, 87. 1932.

Calamovilfa longifolia (Hook.) Scribn. add
C. longifolia var. **magna** Scribn. & Merr.
Amer. Midland Nat. 29: 782. 1943.

Muhlenbergia foliosa (Roem. & Schultes) Trin. to
M. mexicana (L.) Trin.
Rhodora 45: 236. 1943.

Muhlenbergia foliosa f. ambigua (Torr.) Wieg. to
M. mexicana f. **ambigua** (Torr.) Fern.
Rhodora 45: 236. 1943.

Muhlenbergia mexicana (L.) Trin. to
M. frondosa (Poir.) Fern.
Rhodora 45: 235. 1943.

Muhlenbergia mexicana f. commutata (Scribn.) Wieg. to
M. frondosa f. **commutata** (Scribn.) Fern.
Rhodora 45: 235. 1943.

Muhlenbergia racemosa (Michx.) BSP. to
M. setosa (Spreng.) Trin.
Rhodora 45: 237. 1943.

Cenchrus pauciflorus Benth. to
C. longispinus (Hackel) Fern.
Rhodora 45: 388. 1943.

Erianthus alopecurioides (L.) Ell. to
E. saccharoides Michx. var. **compactus** (Nash) Fern.
Rhodora 45: 252. 1943.

Andropogon furcatus Muhl. to
A. Gerardi Vitman
Rhodora 45: 258. 1943.

Scirpus debilis Pursh to
S. Purshianus Fern.
Rhodora 44: 479. 1942.

Scirpus Smithii var. setosus Fern. to
S. Smithii f. **setosus** Fern.
Rhodora 44: 479. 1942.

Scirpus validus Vahl. to
S. validus var. **creber** Fern.
Rhodora 45: 283. 1943.

Carex Grayii Carey, add
C. Grayii var. **hispidula** Gray
Rhodora 44: 322-324. 1942.

Carex lasiocarpa Ehrh. to
C. lasiocarpa var. **americana** Fern.
Rhodora 44: 304. 1943.

Carex laxiculmis var. copulata (Bailey) Fern. to
X **C. copulata** (Bailey) Mack.
Rhodora 44: 388-389. 1942.

Carya Buckleyi Durand var. arkansana Sarg. to
C. texana Buckl. var. **arkansana** (Sarg.) Little
Amer. Midl. Nat. 29: 502. 1943.

Carya tomentosa (Lam.) Nutt. to
C. tomentosa Nutt.
Amer. Midl. Nat. 29: 500-501. 1943.

Morus alba var. tatarica (L.) Loud. to
M. alba var. **tatarica** (L.) Ser.
Rehder: Trees & Shrubs, ed. 2: 188. 1940.

Sisymbrium Thalianum (L.) J. Gay to
Arabidopsis Thaliana (L.) Heynh.
Rhodora 45: 268. 1943.

Barbarea vulgaris R. Br., add
B. vulgaris var. **arcuata** (J. & C.) Fries
Rhodora 45: 304. 1943.

Arabis virginica (L.) Poir. to
Sibara virginica (L.) Rollins
Rhodora 43: 481. 1941.

Arabis viridis var. Deamii Hopkins to
A. missouriensis Greene var. **Deamii** Hopkins
Rhodora 45: 269. 1943.

Prunus virginiana var. demissa Sarg. to
P. virginiana f. Deamii G. N. Jones
Rhodora 45: 355. 1943.

Trifolium hybridum L., add
T. hybridum var. **elegans** (Savi) Boiss.
Rhodora 45: 331. 1943.

Phaseolus polystachus (L.) BSP. to
P. polystachios (L.) BSP.
Rhodora 44: 419. 1942.

Phaseolus polystachus (L.) BSP., add
P. polystachios var. **aquilonius** Fern.
Rhodora 44: 418. 1942.

Angelica villosa (Walt.) BSP. to
A. venenosa (Greenway) Fern.
Rhodora 45: 301. 1943.

Bumelia lycioides (L.) BSP. to
B. lycioides (L.) Gaertn. f. var. **virginiana** Fern.
Ann. Missouri Bot. Gard. 29: 171-172. 1942.

Scutellaria ovalifolia Pers. to
S. ovalifolia var. **hirsuta** (Short) Fern.
Rhodora 44: 433. 1942.

Scutellaria ovata Hill to
S. ovata var. **versicolor** (Nutt.) Fern.
Rhodora 44: 432. 1942.

Monarda fistulosa var. mollis (L.) Benth. to
M. fistulosa L.
Univ. California Pub. Bot. 20: 165. 1942.

Lindernia dubia var, typica Pennell to
L. dubia var. **riparia** (Raf.) Fern.
Rhodora 44: 442-446. 1942.

Lindernia dubia var. major (Pursh) Pennell to
L. dubia (L.) Pennell
Rhodora 44: 442-446. 1942.

Melampyrum lineare Lam. var. latifolium (Muhl.) Beauv. to
M. lineare Desr. var. **latifolium** Barton
Rhodora 44: 452. 1942.

Melampyrum lineare var. pectinatum Pennell to
M. lineare var. **pectinatum** (Pennell) Fern.
Rhodora 44: 452. 1942.

Conopholis americana (L. f.) Wallr. to
C. americana (L.) Wallr.
Gray Syn. Flora ed. 2: 455. 1886.

Solidago media (Greene) Bush to
S. graminifolia var. **media** (Greene) Harris
Rhodora 45: 413. 1943.

Solidago remota (Greene) Friesner to
S. graminifolia var. **remota** (Greene) Harris
Rhodora 45: 413. 1943.

Tragopogon pratensis L. add
T. dubius Scop.
Rhodora 45: 413. 1943.
See also Kearney and Peebles Fl. Plt. Arizona, 1023. 1942.

Hieracium canadense Michx. to
H. canadense var. **fasciculatum** (Pursh) Fern
Rhodora: 45: 320. 1943.

DELETIONS

The following deletions should be made from the State Flora Catalog. *Panicum spretum*, Steuben: drop the county for this species. *P. microcarpon*: drop Elkhart, Lagrange and Starke counties for this species. *Scirpus smithii*: drop Lake, Porter and Starke counties. Correct record to date is La Porte (D), Marshall (D), Kosciusko (D), and Whitley (D). *S. smithii* forma *setosus* Fern.: Rhodora 44: 479. 1942. Drop Lake and La Porte counties. Correct record to date is Cass (D), Jasper (D), Noble (D), Porter (D), Starke (D), Steuben (D). *Saxifraga pennsylvanica* ssp. *interior* var. *winnebagoensis*: change Clark (NW) to Lake (M).

State Flora Committee:
CHARLES C. DEAM, *Chairman*
RALPH KRIEBEL
T. G. YUNCKER
RAY C. FRIESNER, *Secretary*

CHEMISTRY

Chairman: EDWARD J. HUGHES, Eli Lilly and Company

Mr. F. B. Wade, Shortridge High School, Indianapolis, was elected chairman of the section for 1944.

An experiment for freshmen to place emphasis upon Avogadro's number. F. J. ALLEN, Purdue University.—In *Science* for July 17, 1942, a more precise value for Avogadro's number, 6.02331×10^{23} has been reported, based on X-ray studies of crystal structure. Millard's *Physical Chemistry* 5th edition gives a brief statement to show the sort of calculation involved, but the very excellent paper of DuMond and Bollman, (Physical Review *50*, 524-537, 1936) should be consulted for a detailed description of the experimental apparatus and a thorough-going discussion. A proper concept of this number is of such importance that it should be stressed in every reasonable way in the elementary study of chemistry.

A slight modification of a well-known experiment has suggested itself as a suitable stimulus to interest. Into a two-quart bottle with a wide mouth and screw-top is placed some lumps of calcium chloride and a 50 ml. graduated cylinder containing some water. The water level in the graduated cylinder can be read with fair precision without opening the containing bottle. Readings are obtained over a period of days and the rate of evaporation calculated in terms of molecules of water per second.

If the level has fallen 3 ml. in 14 days, one may calculate:

$$\frac{3\text{ g. }H_2O \times \dfrac{1\text{ mole }H_2O}{18\text{ g. }H_2O} \times \dfrac{6.02 \times 10^{23}\text{ molecules of }H_2O}{1\text{ mole of }H_2O}}{14\text{ days} \times \dfrac{24\text{ hours}}{1\text{ day}} \times \dfrac{60\text{ min.}}{1\text{ hr.}} \times \dfrac{60\text{ sec.}}{1\text{ min.}}}$$

to indicate an evaporation of approximately 8.3×10^{16} molecules of water per second.

Numerous variations may occur to teachers and students. One may calculate the evaporation in terms of molecules per second per square millimeter of surface. In place of the apparatus described one may use desiccators with different drying agents and with the water in pipetted amounts in petri dishes. Solutions may be substituted for water. The quantity of drying agent may be varied to see how much the evaporation slows down as the agent becomes "spent".

Sublimation rate in molecules per second may be calculated by ascertaining the time for a weighed sample of naphthalene to disappear.

For short time experiments one might dilute a standard solution of silver nitrate to a point beyond which addition of iodide crystals fails to show turbidity and calculate the number of silver ions per ml.

Experiments of the sort that have been mentioned are suggested primarily in the nature of projects for the class, for the class and teacher, or for the teacher, as circumstances warrant. They may be adapted to a long or short time basis. The object of this paper will be served if it causes even a few students to become more friendly with the Avogadro Constant.

Studies on the detection of oxygen in organic compounds. KENNETH N. CAMPBELL, BARBARA K. CAMPBELL and S. JOAN KING, University of Notre Dame.—Reliable qualitative tests have been devised for the detection of the elements commonly present in organic compounds, with the exception of oxygen. The object of the present work was to make a critical study of the few methods that have been proposed for the detection of organic oxygen, and to attempt to develop new methods.

A solution of iodine in benzene has been shown by others to change from a violet color to a brown one on the addition of an oxygen-containing compound. This test was found to be fairly reliable when positive, provided the organic compound did not contain iodine; a negative test was shown to be of little value, as many of the higher, more inert oxygen compounds, such as benzophenone, triphenylcarbinol, etc., failed to give the test.

The Davidson ferric thiocyanate test was found to be more reliable when negative than when positive. Practically all the oxygenated compounds tried gave a positive test, but many non-oxygenated ones did also, due to the presence of small amounts of oxygen-containing impurities. The thiocyanates of copper, chromium, cobalt and nickel were less satisfactory than the ferric derivative.

Attempts to use anhydrous cupric chloride, and similar metal chlorides as the basis of a test for oxygen failed. Some dyes were found which were more soluble in oxygenated liquids than in others, but the method could not be used with solids. The most satisfactory test so far is the ferric thiocyanate test.

Fundamental techniques of quantitative analysis. E. ST. CLAIR GANTZ, Purdue University (with the technical assistance of J. P. SCOTT and E. C. WERNER, Wabash College).—A moving picture. This 16 mm. film shows in detail the fundamental laboratory procedures for chemistry students as illustrated by the determination of calcium in bone ash.

Calcium can be precipitated as the oxalate, redissolved and the oxalate determined by titration with standard potassium permanganate solution. Using these reactions as a basis the following techniques are illustrated: drying the sample, the use of the analytical balance, solution, precipitation, digestion, filtration, volumetric titration and the recording of data.

The progress of chemurgy with special reference to Indiana crops. EDWARD J. HUGHES, Eli Lilly and Company.—The meaning of the word

"chemurgy" is now generally understood to include the activities of creative industrial chemistry, particularly as they apply to the utilization of agricultural products.

The recent acceleration of the chemurgic movement, leading to the development of new uses for surplus commodities and toward the industrial utilization of agricultural wastes and residues, is of primary concern to the chemist. The necessities of war are rapidly teaching us new methods of approach to the problem of establishing and maintaining a prosperous peace.

Through the combined efforts of the chemist, the bacteriologist and the engineer we are beginning to realize that the blessings of a more abundant life may be obtained by more intelligently drawing upon its abounding natural benefits that are constantly being renewed with the return of the seasons.

The central location of the agricultural State of Indiana places us in a very favorable position to make substantial contributions to the industrial and economic development of the Middle West.

The discussion includes some references to the opening of new industrial markets for our agricultural products, a brief consideration of the risks that may be involved in the absence of adequate knowledge and preparation, and also a few suggestions regarding the possibilities for future progress.

Some reactions of nitrogen peroxide with organic compounds. J. L. RIEBSOMER, DePauw University.—In this paper typical reactions of Nitrogen Peroxide with organic compounds such as nitration, oxidation, addition to olefins, etc., will be discussed. The new work which has been done up to the present is the reaction of nitrogen peroxide on certain ketones and on the alkali metal salts of certain acids producing the corresponding acid anhydrides. The experimental work is at this moment incomplete and not yet ready for publication.

p-Methoxyphenylisothiocyanate as a Reagent for the Identification of Amines

KENNETH N. CAMPBELL, BARBARA K. CAMPBELL and S. JOELA PATELSKI,
University of Notre Dame

Phenylisothiocyanate is one of the most satisfactory reagents available for the identification of primary and secondary amines, since it reacts readily with them, and usually gives crystalline derivatives which are formed in good yield and are easily purified. Unlike its oxygen analog, phenylisothiocyanate does not react with water, and hence the amines do not have to be anhydrous; this is a distinct advantage in the case of many of the lower, water-soluble amines. There is, however, one draw-back to the general use of phenylisothiocyanate; the derivatives which it forms with the lower aliphatic amines are apt to be oils or low-melting solids, and consequently, are not ideal derivatives.

When a methoxyl group is introduced into an aromatic ring, it tends to raise the melting point of the compound, and to make it more crystalline. For this reason we considered it of interest to investigate the use of p-methoxyphenylisothiocyanate as a derivative reagent for amines. This compound has been prepared earlier,[1] but its reactions with amines were not studied.

We synthesized p-methoxyphenylisothiocyanate by the method previously described,[1] using p-anisidine, carbon disulfide and phosgene:

$$CH_3O{-}C_6H_4{-}NH_2 + CS_2 + NH_4OH \longrightarrow [CH_3O{-}C_6H_4{-}NH{-}CS_2^-]$$
$$NH_4^- + COCl_2 \longrightarrow CH_3O{-}C_6H_4{-}N{=}C{=}S + NH_4Cl + COS + HCl$$

The product obtained by this reaction was a light yellow oil.

We found that p-methoxyphenylisothiocyanate reacted smoothly with most primary and secondary amines, both aliphatic and aromatic. In most cases the reaction was spontaneous and exothermic, and a solid derivative formed at once. The derivatives were usually obtained in good yield, and were easily purified to constant melting point by recrystallization from 95% alcohol.

About thirty amines were used in this work. Of this number two, namely propylamine and dipropylamine, gave oils which could not be made to solidify at room temperature, and two, m-nitroaniline and 2,4-dinitroaniline, failed to react with the reagent. The diamines gave the di-p-methoxyphenylthioureas, as shown by the analyses. The p-methoxyphenylthioureas were compared with the corresponding phenylthioureas; in most cases the p-methoxy compounds melted as high as, or higher than, the unsubstituted analogs. Since some of the phenylthioureas were not listed in Shriner and Fuson[2] we prepared them. The data are recorded in Table I.

Experimental Part

Reagents.—The p-methoxyphenylisothiocyanate was prepared by the method of Slotta and Dressler[1]; it boiled at 129-130°/8 mm. The amines, and the phenylisothiocyanate were obtained from the Eastman Kodak Company, and were used without purification.

p-Methoxyphenylthioureas.—Approximately equal volumes of the amine and reagent were mixed in a 3-inch Pyrex test tube. Usually a reaction occurred spontaneously, with evolution of heat. When this had subsided, or if it did not occur, the mixture was warmed gently over a small free flame for a few minutes, and was then allowed to cool. If no solid separated the oil was rubbed with a glass rod, and was chilled in an ice bath. Usually at this point a solid product was obtained. Occasionally it was necessary to warm the mixture again for a few minutes.

The solid reaction product was washed with a few milliliters of cold 95% alcohol, and was then recrystallized from a small amount of the same solvent, until the melting point did not change. Representative derivatives were analyzed for nitrogen by the semi-micro Dumas procedure, and a close agreement was obtained in all cases between the observed and calculated values.

Phenylthioureas.—These were prepared by the same procedure described above for the p-methoxyphenylthioureas.

Summary

The use of p-methoxyphenylisothiocyanate as a reagent for the identification of amines is described. The p-methoxyphenylthioureas of about thirty amines have been prepared and their melting points tabulated. These derivatives have been compared with the corresponding unsubstituted phenylthioureas.

References

1. Slotta and Dressler, Ber. deutsch. Chem. Gesell., **63**, 888 (1930).
2. Shriner and Fuson, *The Systematic Identification of Organic Compounds*, 2nd ed., John Wiley and Sons, New York, p. 126 (1940).

TABLE I.—P-METHOXYPHENYLTHIOUREAS AND PHENYLTHIOUREAS

Amine	p-Methoxyphenylthiourea M. P. °C.	% N obs'd	% N calc'd	Phenylthiourea M. P. °C.
Diethyl	104–105	.		34
n-Propyl	oil		. .	63
Di-n-propyl	oil	. .	. . . .	69
n-Butyl	74	12.10	12.01	65
Di-n-butyl	82	.	. . .	86
iso-Butyl	112	. .		82
n-Amyl	82.5	. .	.	69
n-Heptyl	89		. . .	75
Cyclohexyl	135	10.41	10.60	148–149*
Dicyclohexyl	94–95	.	. .	88–89*
Piperidine	145–146	10.95	11.10	98–99*
Benzyl	109	.	. .	153–154*
Dibenzyl	117	7.64	7.73	144–145*
α-Phenylethyl	112.5	9.66	9.78	103–105*
Aniline	143	10.63	10.85	154
N-Methylaniline	102–103	.		87
N-Ethylaniline	99	9.69	9.78	89
o-Toluidine	139	. . .	. . . .	136
m-Toluidine	139–140	. . .	. . .	94
p-Toluidine	148.5	10.53	10.29	141
p-Anisidine	187	9.93	9.72	157
p-Bromoaniline	178–179	.	. .	148
o-Chloroaniline	155	9.82	9.57	156
α-Naphthylamine	162–163	.	. .	165
β-Naphthylamine	160	8.91	9.09	182–183
p-Aminobiphenyl	193–194	8.27	8.38	. . .
Ethylene diamine	189–190 d	14.17	14.35	187–190*
Piperazine	245–250 d	. . .	. .	. . . . . .
Benzidine	235 d	10.91	10.89	304–305*

* These phenylthioureas were prepared in the course of the present work.

Relative Electronegativity IV. An Empirical Rule as a Teaching Tool

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In any discussion dealing with the teaching of organic chemistry, one must not lose sight of the complexity of most organic reactions (2). The reaction of methyl iodide with ethyl iodide, in the presence of sodium in dry ether, may be formulated as:

$$CH_3{\cdot}I + 2Na/(\text{dry ether}) + I{\cdot}CH_2{\cdot}CH_3 \rightarrow CH_3{\cdot}CH_2{\cdot}CH_3, \text{ propane} + 2NaI.$$

Actually, however, there are two important competing reactions which may be written, namely:

$$CH_3{\cdot}I + 2\,Na/(\text{dry ether}) + I{\cdot}CH_3 \rightarrow CH_3{\cdot}CH_3, \text{ ethane} + 2\,NaI, \text{ and}$$
$$CH_3{\cdot}CH_2{\cdot}I + 2\,Na/(\text{dry ether}) + I{\cdot}CH_2{\cdot}CH_3 \rightarrow CH_3{\cdot}CH_2{\cdot}CH_2{\cdot}CH_3, \text{ butane} + 2\,NaI.$$

Although these three equations indicate the principal products that are obtained in this particular reaction, they do not suggest the production of both olefins and higher alkanes as a consequence of a free radical mechanism or its equivalent.

Considering this reaction in terms of a free radical mechanism, a number of things may happen. The sodium atom may abstract the iodine atom from the methyl iodide to give a methyl radical, as:

$$CH_3{\cdot}I + Na/(\text{dry ether}) \rightarrow NaI + CH_3^\circ, \text{ methyl radical},$$

or a similar abstraction of the iodine atom from ethyl iodide will yield the ethyl radical in accordance with the equation:

$$CH_3{\cdot}CH_2{\cdot}I + Na/(\text{dry ether}) \rightarrow NaI + CH_3{\cdot}CH_2^\circ, \text{ ethyl radical}.$$

These free radicals in turn may enter into any one of a number of reactions, as indicated by the following series of equations:

1. $CH_3^\circ + CH_3^\circ/(\text{dry ether}) \rightarrow CH_3{\cdot}CH_3$, ethane, or
2. $CH_3^\circ + CH_3{\cdot}CH_2^\circ/(\text{dry ether}) \rightarrow CH_3{\cdot}CH_2{\cdot}CH_3$, propane, or
3. $CH_3{\cdot}CH_2^\circ + CH_3{\cdot}CH_2^\circ$, by disproportionation $\rightarrow CH_3{\cdot}CH_3 + H_2C{:}CH_2$, or
4. $CH_3{\cdot}CH_2^\circ + CH_3{\cdot}CH_2{\cdot}CH_3$, by abstraction of H $\rightarrow CH_3{\cdot}CH_3 + CH_3{\cdot}CH_2{\cdot}CH_2^\circ$, then
5. $CH_3{\cdot}CH_2{\cdot}CH_2^\circ + CH_3{\cdot}CH_2^\circ \rightarrow CH_3{\cdot}CH_2{\cdot}CH_2{\cdot}CH_2{\cdot}CH_3$, pentane, or
6. $CH_3{\cdot}CH_2{\cdot}CH_2^\circ + CH_3{\cdot}CH_2{\cdot}CH_2^\circ \rightarrow CH_3{\cdot}CH_2{\cdot}CH_2{\cdot}CH_2{\cdot}CH_2{\cdot}CH_3$, hexane, or
7. $CH_3{\cdot}(CH_2)_n^\circ + Na \rightarrow CH_3{\cdot}(CH_2)_n{\cdot}Na$, sodium alkyl, and
8. $CH_3{\cdot}(CH_2)_n{\cdot}Na + R{\cdot}I \rightarrow CH_3{\cdot}(CH_2)_n{\cdot}R$, an alkane $+$ NaI.

Variations of these eight reactions give rise to a large number of theoretically possible products, all of which are predictable if the results are interpreted in terms of a free radical or equivalent mechanism.

This preliminary discussion emphasizes the importance of *several* factors in determining the progress of a reaction. These are tabulated in Table I and must be considered *individually* and *collectively,* in postulating the course of any organic reaction.

Table I. Factors That Determine the Progress of a Reaction

I. Equilibrium, as determined by:

A. The pressure, B. The temperature, and C. The solvent.	$\left\{\right.$ These are important only because they change the ΔF, which determines the equilibrium.

II. Rate, as determined by:
- A. The pressure,
- B. The temperature,
- C. The concentration, and
- D. The mechanism, which may be in turn a function of:
  1. The absence or presence of a catalyst,
  2. The absence or presence of an inhibitor, and
  3. The formation of an unstable intermediate, a momentary addition compound, or an activated complex.

If Table I is approximately correct, it becomes apparent that the progress of any reaction is concerned with a number of factors. The less these variables deviate from ordinary experimental conditions, the more nearly one approaches an appraisal of the normal reactivity of a compound.

Another item for consideration in the teaching of organic chemistry is the correlation of this branch of the science with general chemistry. All too frequently the student is given the impression that general chemistry is one science and that organic chemistry is something quite different. This concept most frequently arises, perhaps, in the consideration of valence. The valence bonds of organic molecules are too often considered as typically non-polar, whereas those of inorganic compounds are regarded as polar. That this difference is one of degree rather than one of type is illustrated by the equations:

$Na^{+}\,{}^{-}Cl$, inorganic solid $+ H_2O$, excess $\rightarrow Na^{+} + Cl^{-} + H_2O$, and

$Na^{+}\,{}^{-}O{\cdot}OC{\cdot}CH_3$, organic salt $+ H_2O$, excess $\rightarrow Na^{+} + {}^{-}O{\cdot}OC{\cdot}CH_3 + H_2O$, and

$Na^{+}\,{}^{-}C\vdots C{\cdot}H$, organic solid $+ H_2O \rightarrow H{\cdot}C\vdots C{\cdot}H$, gas $+ Na^{+} + OH^{-}$.

These equations emphasize the *relative* nature of the phenomena and indicate that in organic chemistry we should use the terms relatively electronegative and relatively electropositive instead of electronegative and electropositive (1, 3).

The relative positions of the electrons in a given system are a function of the system itself, as indicated in Figure I. In the system CH_4, CI_4, CBr_4, CCl_4 and CF_4, there is reason to believe that the electrons are displaced progressively away from the central carbon atom as the substituent groups become more strongly electronegative (or electron-attracting).

In Fig. 1 the problem of relative electronegativity has been considered from the *qualitative* viewpoint only. By a consideration of bond energies, however, Pauling has been able to evaluate the *relative* polarity of various types of bonds and set up an electronegativity map (cf Fig. 1, and Table I (3, a).

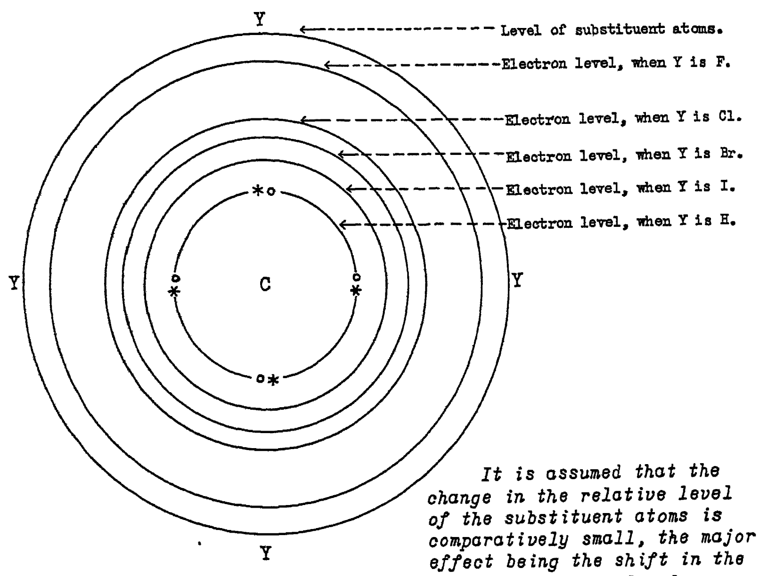


Fig. 1. Electron Level Chart. Showing the relative positions of electrons in CH_4, CI_4, CBr_4, CCl_4, and CF_4, where Y represents a hydrogen, iodine, bromine, chlorine, or fluorine atom. It is recognized that the bond distance varies with the nature of the substituent atom. The C-Br bond has a value of about 1.95 Å, and the C-Cl bond has a value of 1.81 Å, whereas the distance of the C-I bond is a little larger and that of the C-H and C-F bonds are somewhat less. Nevertheless, the general concept pictured in Figure 1 is believed to be valid.

The electronegativity map presents a graphic representation of the relative electronegativity of the various atoms with respect to the carbon atom which lies at 2.5. The atoms which lie to the right of 2.5 tend to displace the electrons away from the carbon to which they are attached, whereas those to the left of 2.5 tend to displace the electrons toward the carbon atom to which they are bonded.

This concept of the relative electronegativity of the constituent atoms of an organic molecule enables one to set up certain postulates (Table II),

which serve as a basis for predicting certain chemical properties of the compound.

Table II. Postulates of the Theory of Relative Electronegativity

1. The relative distribution of the electrons in methane is assumed to represent the condition of maximum stability for a carbon-hydrogen or hydrocarbon system, the other extreme case of stability being represented by carbon dioxide, carbon tetrafluoride, and other highly oxidized compounds.
2. Replacement of a hydrogen atom in a hydrocarbon or its derivative by a more or less strongly electronegative group is attended by a consequent distortion of the *relative* positions of the electrons.
3. Any distortion of the electron distribution from that of methane will result in a reduction in the stability of the compound so formed, and the instability will be proportional to the distortion until complete displacement of the electrons (or oxidation) is obtained.
4. Any distortion in the relative distribution of the electrons tends to be distributed throughout the system, the effect diminishing with remoteness from the point of disturbance.
5. The influence of any atom on the relative distribution of the electrons is assumed to be a function of the *relative* electronegativity of the atom concerned as indicated by the Electronegativity Map. On this basis a hydrogen atom is assigned a value of +1, an iodine or sulfur[1] atom a value of 0, a bromine atom a value of —0.75, a chlorine atom a value of —1.25, a nitrogen atom a value of —1.25, a single bonded oxygen atom a value of —2.5, and a double bonded oxygen atom a value of *something less* than —5.

By use of the postulates of Table II, it becomes possible to predict *qualitatively* the so-called addition reactions of organic compounds as indicated in Table III.

Table III. Prediction of Addition Reactions in Terms of Relative Electronegativity

1. The principal course of an olefin addition reaction, of which over two hundred fifty cases have been tabulated from the literature, is predictable by this rule with an accuracy of over 95%.
2. Every case of so-called 1,4-addition considered in terms of these postulates follows the course predictable by this rule.
3. The cases of vinylogy thus far considered are in keeping with the predictions of these postulates.
4. The addition reactions of the carbonyl group of the aldehydes and ketones are in agreement with this theory.

[1] More recent data indicate that the sulfur atom is slightly positive with respect to the carbon atom.

5. The addition products of the nitriles, isonitriles, and similar unsaturated systems are predictable by use of these concepts.
6. Complex addition reactions such as that between (a) isobutylene and isobutane, (b) vinyl chloride and itself, (c) vinyl acetate and itself, (d) methyl methacrylate and itself, (e) isoprene and itself, and others too numerous to mention, may be predicted *qualitatively* by use of this general rule of relative electronegativity and its attendant postulates.

Consider, for example, the addition reaction of propylene with hydrogen fluoride, water, hydrogen chloride, hydrogen bromide, hydrogen iodide, chlorine fluoride, bromine fluoride, iodine fluoride, bromine chloride, iodine bromide, and hypochlorous acid. Qualitatively, the results are somewhat similar; but when quantitative data are considered it might be expected that the results would be a function of the *relative* electronegativities of the atoms concerned. Unfortunately, data are not available for this complete series, but the results that have been tabulated are in agreement with the predictions, as indicated in Table IV.

Table IV. Data That Require the Existence of Competing Reactions

$CH_3{\cdot}HC\overset{+-}{=}CH_2 + HO{\cdot}H$	$\rightleftarrows CH_3{\cdot}CHOH{\cdot}CH_3$, 9 to 10 parts to
	$\rightleftarrows CH_3{\cdot}CH_2{\cdot}CH_2{\cdot}OH$, 1 to 0 part, and
$CH_3{\cdot}HC\overset{+-}{=}CH_2 + Cl{\cdot}H$[1]	$\rightleftarrows CH_3{\cdot}CHCl{\cdot}CH_3$, 5 to 6 parts to
	$\rightleftarrows CH_3{\cdot}CH_2{\cdot}CH_2{\cdot}Cl$, 1 to 0 part, and
$CH_3{\cdot}HC\overset{+-}{=}CH_2 + Cl{\cdot}I$[6]	$\rightleftarrows CH_3{\cdot}CHCl{\cdot}CH_2{\cdot}I$, 3 parts to
	$\rightleftarrows CH_3{\cdot}CHI{\cdot}CH_2{\cdot}Cl$, 1 part, and
$CH_3{\cdot}HC\overset{+-}{=}CH_2 + Cl{\cdot}Br$[6]	$\rightleftarrows CH_3{\cdot}CHCl{\cdot}CH_2{\cdot}Br$, 7 parts to
	$\rightleftarrows CH_3{\cdot}CHBr{\cdot}CH_2{\cdot}Cl$, 5 parts, and
$CH_3{\cdot}HC\overset{+-}{=}CH{\cdot}Br + HI$[5]	$\rightleftarrows CH_3{\cdot}CHI{\cdot}CH_2Br$, 2 parts to
	$\rightleftarrows CH_3{\cdot}CH_2{\cdot}CHIBr$, 1 part.

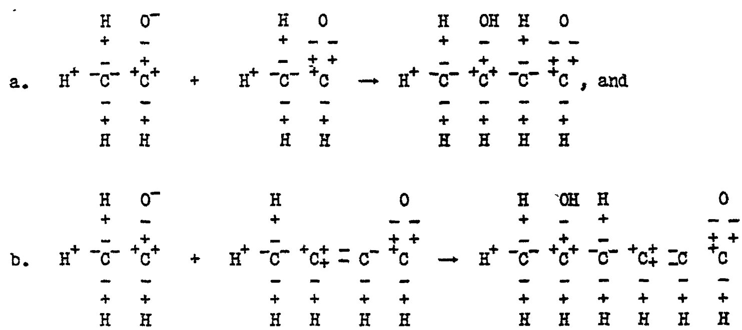
To explain the results of Table IV it seems necessary to assume an equilibrium, such as the following, in which there are competing reactions:

$$CH_3{\cdot}HC\overset{+-}{=}CH_2 \begin{cases} + \overset{-}{Cl}\,\overset{+}{I} \rightleftarrows CH_3{\cdot}CHCl{\cdot}CH_2{\cdot}I, \text{ or} & (1) \\ \qquad \upharpoonleft\!\downharpoonright & \\ + \overset{+}{Cl}\,\overset{-}{I} \rightleftarrows CH_3{\cdot}CHI{\cdot}CH_2{\cdot}Cl, \text{ and} & (2) \end{cases}$$

$$CH_3{\cdot}HC\overset{-+}{=}CH_2 \begin{cases} + \overset{-}{Cl}\,\overset{+}{I} \rightleftarrows CH_3{\cdot}CHI{\cdot}CH_2{\cdot}Cl, \text{ or} & (3) \\ \qquad \upharpoonleft\!\downharpoonright & \\ + \overset{+}{Cl}\,\overset{-}{I} \rightleftarrows CH_3{\cdot}CHCl{\cdot}CH_2{\cdot}I & (4) \end{cases}$$

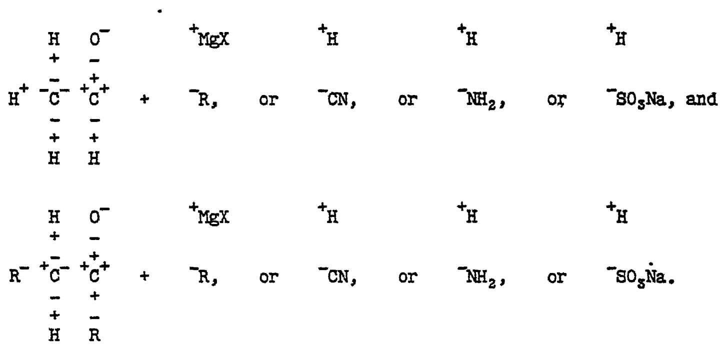
Reactions 1 and 3, presumably, account for most of the products, but as the two atoms adding at the double bond approach each other in *relative* electronegativity there is a corresponding increase in the importance of reactions 2 and 4.

The application of the principle of relative electronegativity to aldol condensation and vinylogy is illustrated by the condensation of acetaldehyde (a) with itself to give aldol, and (b) with crotonaldehyde to give 5-hydroxy-2-hexenal. In each case it is observed that a positive hydrogen atom becomes bonded to a negative oxygen atom, and that a *relatively negative carbon atom* becomes bonded to a *relatively positive carbon atom*, as:

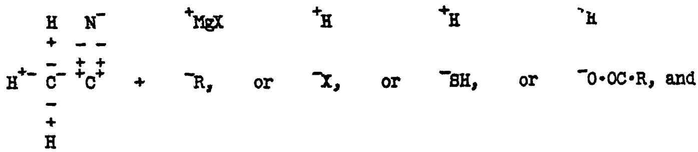


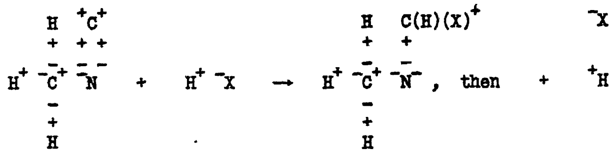
These equations suggest that an H-atom that is bonded to a strongly negative C-atom is the one that is involved in the condensation. There are in the latter case, furthermore, three *gamma* H-atoms to only one *alpha* H-atom.

The addition reactions of the carbonyl group of the aldehydes and ketones occur in such a way that the electropositive atom becomes bonded to the oxygen atom whereas the electronegative atom becomes bonded to the carbon atom as illustrated by:

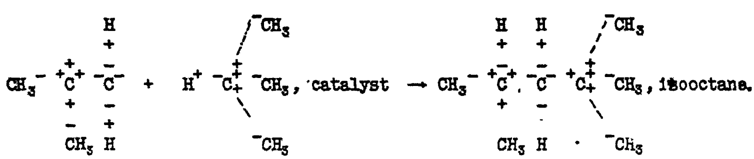


In addition reactions of the nitriles and the isonitriles, similarly, the electropositive atom adds to the nitrogen atom whereas the electronegative atom becomes bonded to the carbon atom, as indicated by:

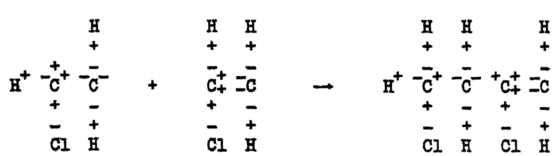




In the reaction-types considered in the preceding paragraphs, it should be noted that all of those involving a carbon to carbon condensation take place so that a relatively positive carbon atom becomes bonded to a relatively negative carbon atom. In each of these cases, the other part of the *addend* became bonded to an atom of the opposite relative polarity. A slightly different case is now considered, in which the *ever-agreeable* hydrogen atom takes the only available position after the relative polarities of the carbon atoms have been satisfied. In the addition of isobutane to isobutylene, a *relatively* electropositive carbon atom becomes bonded to a *relatively* electronegative carbon atom, with the tertiary hydrogen atom in isobutane migrating to the *open* position in the addition complex, as indicated by:



Similarly, vinyl chloride polymerizes in accordance with the equation:



The initial polymerization product adds in turn other units of vinyl chloride, and still others to give a thread-like molecule.

Other *possible* applications of the empirical rule are (1) reactions of the ketenes, (2) ketol-enol isomerism, (3) reactions of butadiene, (4) γ-lactones and δ-lactols, (5) the Knoop *beta*-oxidation theory, (6) ionization of acids, (7) aldol condensation, (8) halogenation, (9) nitration, (10) sulfonation, (11) molecular rearrangement, (12) comparative stability, and (13) orientation. Only the compilation and correlation of

the available data in the literature, together with careful checking of questionable results, will reveal the validity and usefulness of the rule with respect to these several items.

In conclusion, it may be said that:

1. The value of this empirical rule is a direct function of its usefulness.
2. The postulate set forth herewith is given only *as an empirical rule* without any attempt to justify the applicability of the rule by a physical basis.
3. The application of this rule requires the use of the concept of alternate polarity, but without making any claims relative to the validity of the alternate polarity concept, which is generally conceded for conjugated systems but not for saturated systems.
4. The use of the rule necessitates the visualization of the organic molecule as a composite of atoms, with a number of electrical forces, as a consequence of the contribution made by each substituent atom on the chain or nucleus.
5. The rule has been applied qualitatively to over two hundred fifty cases of simple olefin addition with an accuracy of over 95 per cent.
6. Some cases of olefin addition have been considered quantitatively with a very satisfactory agreement between predictable and obtainable results (2).
7. The limitations of the application of this rule (a) to olefin addition, (b) to 1,4-addition, (c) to substitution in both the aliphatic and aromatic series, (d) to molecular rearrangements, (e) to nitrile addition, (f) to cases of vinylogy, (g) to the formation of lactones and lactols, and (h) to *beta*-oxidation, must await amplification until a complete tabulation, correlation, and interpretation of the available data have been made. The completion of these tabulations and the correlation and interpretation of the available data may lead to slight changes in the method of assigning the electronegativity values and of calculating the relative electronegativity (or R.E.) ratio.

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Anode Polishing[1]

FRANK C. MATHERS and ROBERT E. RICKS,[2] Indiana University

The purpose of this research was to test mixtures for use as baths for the anode polishing of metals. Although anode polishing is commercially done, there are some difficulties with, and some objections to, the solutions that are being used. As all have exceptionally high electrical resistance, they become excessively hot during operation. Sufficient heat is developed, unless a good cooling system is used, to char the glycerine which is used in one of the baths along with phosphoric acid. There is danger of an explosion, or at least there is a fire hazard, with the other most commonly used bath which is a mixture of perchloric acid and acetic acid anhydride.

What is needed is a bath of greater electrical conductivity containing constituents that do not char, or burn, or explode, if the temperature does become high. This research succeeded in finding a bath that did not char, burn, or have the possibility of exploding, but it still had a high electrical resistance.

A recent development in electrochemistry is anode polishing. Anodes are not dissolved appreciably in some solutions but become highly polished. Industrially, this is often a more economical method of polishing than any mechanical means. This is especially true of stainless steel, which polishes easily, and for some irregularly shaped articles the surfaces of which cannot be gotten in contact with a polishing wheel.

Anode polishing results[3] from the selective dissolving of the elevations on the metallic surface and can only occur if the rate of dissolution of the elevations is greater than that in the depressions. This is effected when depressions are relatively anodically passive and the elevations relatively anodically active. An anodic film must form which is thinner in the elevations and thicker and more protective in the depressions. The electrochemical behavior of the metal ions anodically formed in the electrolyte governs the nature of this passivating film. This indicates that there is no universal solution and that many different baths would be satisfactory.

This theory explains why the salts formed at the anode must have high solubility and why the solution of these salts and the bath itself must have high viscosity. It also shows why agitation is undesirable; the anode film would be displaced. Such a passivating film and the high viscosity of the bath explains why the electrical resistance is so high. This causes very undesirable heating in most cases. This somewhat

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[1] From a thesis by Herbert E. Ricks for the Ph.D. degree at Indiana University, 1942.

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[3] Pray and Faust, Iron Age, **145**, April 11, 33 (1940).

passive condition of the anode explains the relatively small loss in weight. If the anode loses much weight, etching or corrosion and not polishing results. If an insoluble solid salt forms at the anode, pitting of the anode is the result.

The solutions used[4] are usually phosphoric acid and glycerine or perchloric acid and acetic acid anhydride.

Experimental

Electrolysis was carried out with anodes, 2x2 cm., of the metal or alloy being polished. The cathodes were lead sheets having an area about four times that of an anode. The anodes were cleaned before polishing by degreasing in carbon tetrachloride, dipping in concentrated hydrochloric acid and rinsing in distilled water.

Each electropolished anode was given a polish rating, by inspection, of from one to five (five being the most highly polished and one being the least polished).

The temperature, concentration of components in the bath, and current density were varied. The sample being polished was watched and if only etching or corroding occurred, the anode was replaced by another metal; if polishing occurred the anode was left for ten minutes or until no further polishing occurred.

Temperatures given were maximum temperatures, and were controlled by immersing the bath in cold water or by setting the bath on a hot plate having a bank of lamps in series with the hot plate so that the temperature could be varied. Amperes are per sq. cm. The quantities given are the proportions in which the chemicals were mixed in making the baths.

Stainless Steel

The best bath was 24 ml. of conc. phosphoric acid and 36 ml. of cyclohexanol, $C_6H_{11}OH$ (sometimes called hexahydrophenol). The current density was 0.38 amp. The temperature was 86°. The best time was 5 or, occasionally, 10 minutes. The bath did not char or darken from the high temperature as did the glycerine-phosphoric acid bath. This is an important advantage. The degree of polish was somewhat higher than could be obtained with the commonly used glycerine-phosphoric acid bath.

Other baths tested and their ratings are:

> Sulfuric acid 20 ml., glycerine 15 ml., and 15 ml. of an equal molecular mixture of glycerine and tartaric acid, at 0.30 amp. and 40°; rating 4½ to 5.

> Ammonium acetate 1 gm. and 8 ml. of cyclohexanol at 0.30 amp. and 84°; rating 4.

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[4] The best general references with bibliography are: Tour, Iron Age, **145**, May 23, 56; May 30, 26 (1940); Shaefer, Metal Ind. (N. Y.), **38**, 22 (1940); Tour, Metal Finishing, **38**, 321, 308 (1940).

Glycerine 10 ml., sulfuric acid 4 ml., and water 6 ml. to 0.24 amp. and 86°; rating 4 to 4½.

Pyrophosphoric acid 10 ml., and 10 ml. of cyclohexanol at 0.24 amp. and 105°; rating 4 to 4½.

Pyrophosphoric acid 10 ml. and 12 ml. of dioxan (trimethylene glycol) at 0.23 amp. and 97°; rating 4½ to 5.

Aluminum

The best bath was conc. sulfuric acid 12 ml. and glycerine 24 ml. at 0.25 amp. for 20 minutes. The rating was 5. The presence of water and hydrochloric acid increased the etching. A high current density was necessary and the time was usually 10 to 20 minutes.

Other solutions tried and their ratings are:

Carbowax 2 gm., hydrofluoric acid 4 ml., and aluminum nitrate 2 gm. at 1 amp. and 112°; rating 5.

Phosphoric acid 10 ml. and sulfamic acid, NH_2SO_3H, 3 gms. at 0.65 amp; rating 5.

Phosphoric acid 10 ml. and sulfuric acid 3 ml. at 0.67 amp. and 136°; rating 4 to 4½.

Copper

No entirely satisfactory solution was found. The best ratings were 4½. Phosphoric acid 24 ml. and cyclohexanol 36 ml. at 0.38 amp. and 100° for 5 minutes was perhaps the best one. Various baths such as (a) chromic acid and water; (b) ammonium acetate, glycerine and boric acid; (c) sulfamic acid and phosphoric acid; (d) acetic anhydride and sulfamic acid; and (e) pyrophosphoric acid and cyclohexanol, for 10-30 seconds rated about 4½.

Iron

Iron was difficult to polish, and no entirely satisfactory solution was formed. The best solution was phosphoric acid saturated with citric acid, at 0.22 amp. and 100° for 1 minute. The rating was 4½ to 5. Various combinations similar to those described for the other metals rated 4 to 4½.

Zinc

No satisfactory bath was found but the best result, rating 4½, was obtained with cyclohexanol, 20 ml., and phosphoric acid, 16 ml., at 0.35 amp. and 80° for 2 minutes. Various other combinations rated 4 to 4½.

Fused baths such as 10 gms. of $NaNO_2$, 5 gms. of $NaNO_3$, and 5 gms. of KNO_3, were tried, but they always corroded the metals and did not produce a polish.

Conclusion

The presence of water and halogen ions caused etching rather than polishing.

The resistance of all polishing baths is high. This causes undesirable heating and, when easily decomposed organic compounds are used, serious blackening or charring results.

The most important development of this research was the successful use of cyclohexanol, a chemical that had never been used before in polishing baths. It seemed to be superior to glycerine in the two desirable ways: (1) It did not char when heated, and (2) it produced a little better degree of polish.

The cyclohexanol is insoluble in water which makes washing of the treated metal more difficult than when glycerine is used.

A Study of the Grignard Reaction as Applied to Student Preparations

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The use of Grignard reagents as intermediates in organic synthetic chemistry has become increasingly more important in the forty-three years which have elapsed since V. Grignard (1) succeeded in resolving Barbier's (2) original synthesis of dimethylheptenol from methyl iodide, magnesium and methylheptenone into its now familiar two steps, consisting (a) of the formation of the methyl magnesium iodide, and (b) the coupling of this compound with the carbonyl group of methylheptenone. In the period from 1900 to 1920, following this discovery, there appeared in the literature more than 1500 articles concerning the use and application of Grignard reagents. No present day organic chemist needs to be shown justification of the importance of Grignard reagents, since their versatility is forcibly demonstrated in everyday synthetic work.

The importance of these reagents is duly stressed in lectures in elementary organic chemistry and is frequently somewhat neglected in the laboratory course which accompanies these lectures. The same may be true of other reactions of organic chemistry, such as the Wurtz synthesis, the Friedel-Craft reaction, and others; but justification may be made that these latter syntheses are often difficult for the student to perform properly. Grignard reagents, and compounds formed from them, may, however, be easily prepared with only the reagents and equipment usually available in laboratories devoted to instruction in elementary organic chemistry. In laboratory courses in elementary organic chemistry, one typical Grignard reaction is usually included. Even with adequate experimental directions, however, student yields are frequently very low and in some cases the desired product is not obtained. Since the separative procedures are not difficult, nor different from many others students perform with good results, it appears that the difficulty lies in the formation of the Grignard reagent, or in the coupling reaction which follows. With this thought in mind, the desirability of studying the conditions necessary for a good yield of a Grignard reagent became apparent. To this end, the following experiments were planned.

A typical student preparation of phenyl ethyl carbinol from an ethyl halide, magnesium, and benzaldehyde, by the method of Grignard (1-3), was used as a standard procedure. Conditions were carefully controlled, and in each series of experiments only one variation was permitted in order to show the effect, in terms of percent theoretical yield, on the result. Among the factors affecting the yield are: (a) use of the proper halide, (b) purity or dryness of the ether, (c) manipulation of the reagents during the formation of the Grignard reagent, and (d) exclusion

of atmospheric moisture. With proper attention to these four details, it is shown that an average yield as high as 82.5% of theory can be obtained in this preparation. Careful attention on the part of instructors to these four details should show organic students that the Grignard reaction is a very useful laboratory procedure and not "just another textbook or theoretical reaction."

Experimental

The equipment consisted of a one liter Florence flask fitted with a two-hole stopper and carrying a separatory funnel and water condenser arranged at an angle of 45° for reflux. A small calcium chloride tube was fitted to the upper end of the condenser to exclude atmospheric moisture.

Reagents:

24.4 grams of ethyl bromide or equivalent quantity of ethyl iodide or ethyl chloride.

5.4 grams of magnesium turnings which were new and bright.

150 ml. ethyl ether.

25 grams of freshly distilled benzaldehyde.

The following method, described by Grignard (1-3) was used throughout:

The magnesium is placed in the liter flask, and a solution of the alkyl halide in 100 ml. of ether is placed in the separatory funnel. One-quarter of the alkyl halide-ether solution is then run into the flask, and a period of 5 minutes is allowed for the reaction to start. If, after this time, there is no indication that the reaction has begun, such as a cloudy appearance of the mixture, or a gentle boiling of the ether, a small crystal of iodine is added to the flask. If after another 5 minutes the reaction still has not started, a piece of the magnesium is rubbed with the flattened end of a glass rod; and if this fails, the mixture is gently warmed until the ether just begins to boil. When the initial violence of the reaction has subsided, the remaining ether-alkyl halide solution is allowed to drip in just fast enough to maintain the reaction. Approximately 40 drops per minute is adequate for this operation. After the addition of the alkyl halide, add 25 ml. of ether to the separatory funnel to wash the last traces of the alkyl halide into the flask. Reflux the mixture for 30 minutes. Cool in an ice-bath, and allow the benzaldehyde, mixed with an equal volume of ether, to flow in slowly from the separatory funnel with constant shaking. This should require approximately 20 minutes. Cork and allow the mixture to stand overnight.

Hydrolyze the mixture with 3 N. HCl, adding a sufficient excess to dissolve any unattacked magnesium. Separate the ether layer, wash with 25 ml. of 10% sodium bicarbonate, and then with 25 ml. of 10% sodium bisulfite, and finally with another 25 ml. portion of 10% sodium

bicarbonate solution. Dry the ether solution with anhydrous potassium carbonate, and then distill off the ether and fractionate the residue. Collect the fraction boiling at 200-215° C. as phenyl ethyl carbinol. The theoretical yield, based upon the alkyl halide, is 30.5 grams.

Effect of alkyl halide upon yield. (Series 1)

Since the variety of alkyl halides usually available in the average organic laboratory is somewhat limited, it is frequently necessary to use a chloride, bromide or iodide when one of the other halides is specifically called for by a given procedure. In order to determine whether a resulting increase in yield would justify the additional work of preparing the required halide, the following series of experiments was carried out: Samples of phenyl ethyl carbinol were prepared using as starting materials ethyl chloride, ethyl bromide and ethyl iodide, with all other conditions exactly as described above. Ethyl bromide gave 82.5% of theory, while ethyl chloride gave 78.9% of theory and ethyl iodide gave 68.6% of theory. (All percentage results are averages of at least three experiments.)

Effect of grade of ether upon yield. (Series 2)

In the many procedures examined, various directions were found for preparing the ether. Some of these were time consuming and wasteful, or otherwise undesirable, and so to determine exactly the effect of various grades of ether on the yield, ether samples of different quality were used. These were:

(a) Ether dried over metallic sodium and distilled over metallic sodium.

(b) Ether dried over calcium chloride for two weeks.

(c) Ether dried over calcium chloride for 24 hours.

(d) Ether dried over calcium chloride for 1 hour.

(e) Ether used as purchased. (Contained water and about 3.5% ethyl alcohol.)

(f) Absolute ether which had been saturated with water.

The results are given in Table I.

Effect of improper manipulation of reagents on yield. (Series 3)

The procedure for preparing phenyl ethyl carbinol described above may be made somewhat simpler, both in amount of time required and in the complexity of equipment needed, by mixing all the alkyl halide with the ether, and then adding the magnesium and refluxing or controlling the reaction by suitably cooling the mixture. The following experiments were conducted to determine the justifiability of the longer method. Ethers of the same grades as used in Series 2 were used and all conditions remained the same with the exception that the entire quantity of the

alkyl halide-ether solution was added to the magnesium at once, and, if the reaction became violent, the mixture was cooled with an ice-bath. The results are given in Table I.

Effect of atmospheric moisture on yield. (Series 4)

In this series of experiments all of the conditions of the second series were duplicated with the exception that the calcium chloride tube was removed from the upper end of the condenser, thus allowing the reaction mixture to be in contact with atmospheric moisture during the time of addition of the alkyl halide, refluxing, and addition of the benzaldehyde (about 1½ hours in all). The results are given in Table I.

Discussion

Under the best conditions of the procedures used, an average yield of 82.5% of theory was obtained. The experiments clearly show: (a) The choice of the proper alkyl halide is essential to good yield. In these experiments the iodide gave a low yield probably because of the tendency of one mole of the alkyl magnesium iodide to react with another mole of the alkyl iodide to form an alkane as suggested by Gilman and West (4). The chloride and the bromide gave essentially the same yields but the handling of the volatile ethyl chloride makes its use impractical in a student preparation. (b) Improperly dried ether, or ether containing ethyl alcohol, was found to cause a serious depression in the yields. With ether which had been saturated with water the desired product was never obtained, and with ethers which had been dried over calcium chloride yields were at least 20% lower than those obtained under an ideal condition of absolute ether. With absolute ether, it was found unnecessary to resort to catalytic devices, such as iodine, to start the reaction, except in the case of the unreactive chloride. Many such devices are suggested in the literature (5, 6, 7, 8, 9, 10, 11) and the three most common are incorporated in the procedure to be used if necessary. Since the use of iodine was found unnecessary in experiments using absolute ether, the washing of the ether solution of phenyl ethyl carbinol with sodium bisulfite could have been eliminated and the yields probably increased. For the sake of uniformity in these experiments, all samples were washed with sodium bisulfite solution. With even traces of water present in the ether, it was necessary to use iodine, and, in some instances, the other two catalytic methods to start the reaction. (c) Proper manipulation of the reagents was found to be another essential feature. For example, if all of the alkyl halide, in its ether solution, was added to the magnesium at one time and the reaction controlled with cooling, the reaction at times was too vigorous to control. Flooding of the condenser with considerable loss of ether sometimes resulted, and at other times, the reaction would stop completely and the mixtures would have to be warmed gently to start again. Yields in every instance were some 20% lower than those experiments in which the alkyl halide-ether mixture was added slowly to the magnesium. (d) The exclusion of atmospheric moisture, by the use

of a calcium chloride tube fitted to the upper end of the condenser, was found essential, since yields dropped from 10 to 20% when this item of equipment was eliminated.

All of the above experiments were controlled so that they could be completed in two three-hour laboratory periods.

The above experimental results constitute a summation of research which has been presented before by many authors. It is hoped, however, that from these results, instructors of elementary organic chemistry will find some helpful facts which will enable them to show the student more satisfactorily the value of the Grignard reaction.

TABLE I.

Grade of Ether	Average % of Theoretical Yield* *Series 2*	*Series 3*	*Series 4*
Ether dried over metallic sodium	82.5	58.7	52.7
Ether dried over calcium chloride for two weeks	60.4	42.6	40.8
Ether dried over calcium chloride for 24 hours	59.7	44.7	39.4
Ether dried over calcium chloride for 1 hour	58.4	35.6	36.5
Ether as purchased (contained approx. 3.5% ethyl alcohol)	42.8	22.7	28.9
Absolute ether which had been saturated with water	0.0	0.0	0.0

* All percentages are averages of at least three experiments.

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GEOLOGY and GEOGRAPHY

Chairman: W. T. BUCKLEY, Indiana University (in armed services)
Acting Chairman: W. D. THORNBURY, Indiana University

Professor A. H. Meyer, Valparaiso University, was elected chairman of the section for 1944.

Indiana County Contrasts in Population Changes

STEPHEN S. VISHER, Indiana University

Of Indiana's 92 counties, only 16 have increased in population decade by decade. The remaining nearly five-sixths of the counties, after attaining their maximum population some time ago, most of them before 1900, have suffered a decline. Thirteen of these counties have continued to decline progressively at each census since their maximum population and five others lost each time except in 1930, when they had a few more people than in 1920. The remaining 58 counties or nearly two-thirds of the state's total, have fluctuated notably during recent decades; most of them had more people in 1940 than in 1930 or 1920.

Population distribution and changes are highly significant aspects of the geography of a region and are worthy of prolonged study to disclose the facts and, if possible, to arrive at their basis. The present study is in continuation of one published in the *Proceedings* in 1942 on "Population Changes in Indiana 1840-1940." (51:179-193)

The first of the accompanying maps shows by vertical shading the 16 counties that have increased steadily in population, and by horizontal shading the 13 which have declined census by census since attaining their maximum population (mostly in 1870-1890) and also the five which declined steadily except for 1930 (Lawrence, Miami, Orange, Rush, Shelby, encircled in Figure 1). The remaining unshaded counties have had a varied population record, that is, have changed status in recent decades.

Map 1 shows that the 16 counties which have continuously gained in population are mostly those with relatively large cities. Examples are Marion (Indianapolis), Allen (Ft. Wayne), Lake (Gary), St. Joseph (South Bend), Vanderburg (Evansville) and Delaware (Muncie). Others are LaPorte (Elkhart), Tippecanoe (Lafayette), Howard (Kokomo) and Wayne (Richmond). Five other counties which have continuously gained although they do not have especially large cities are Henry (New Castle), Fayette (Connersville), Johnson (Franklin), Monroe (Bloomington) and Floyd (New Albany). Four of these 16 relatively prosperous counties are on the northern border of the state, two are on the Ohio River, and the remainder are more centrally located.

The counties which had more people at the 1940 census than at any earlier one are diagonally crossed in Figure 3. The counties that first declined in population are mostly near the southeastern corner of the state, the first part to be well settled. Declines set in there soon after 1870 for Franklin, Jefferson, and Ohio counties and soon after 1880 in several other counties. Owen County also commenced to decline before 1880, and Putnam, Hendricks, Warren and Lagrange before 1890. Five counties, scattered from Crawford on the Ohio River to Whitley just west of Ft. Wayne, had their maximum populations in 1890. Aside from the 16 counties which grew until 1940 (see Fig. 1), most of the remaining counties had their maximum populations no later than the 1900 census. (The census date of maximum population for each county is shown in the 1942 *Proceedings* article cited, Figure 6.)

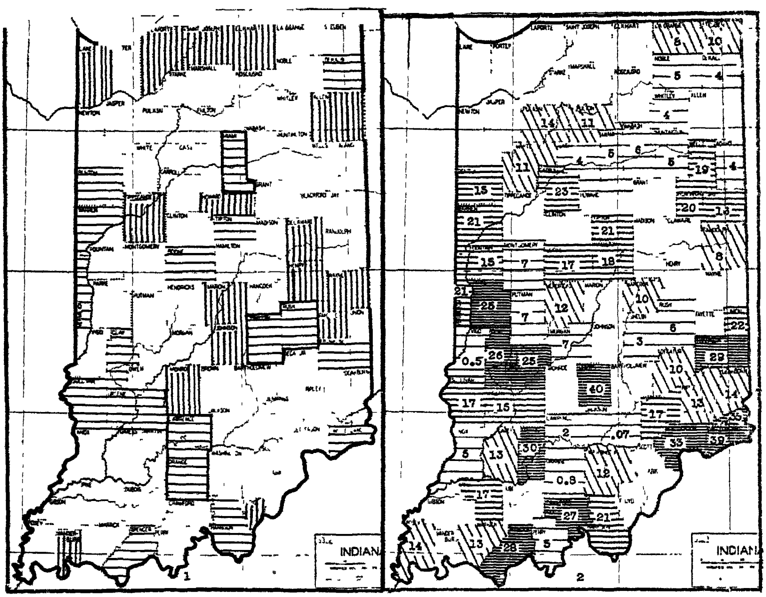

Fig. 1. Counties classified as to population growth: counties shaded vertically had continuous growth; counties shaded horizontally had a steady decline during recent decades; unshaded counties have recommenced increasing after a decline, or were irregular.

Fig. 2. Percentage of decline in population from census of maximum (mostly in 1870-1900) to 1940. Unshaded counties have continued to gain.

The extent of loss of population between the census of maximum population and 1940 is indicated by Figure 2. The shading here represents the percentage magnitude of the loss, the darkest shading, a loss of 25-40 per cent; next one of 15-24, and third (diagonals) one of 10-14 per cent.

The counties which have lost most heavily, relatively, are Brown, Switzerland, Ohio, Jefferson and Martin (40, 39, 35, 33, and 30 per cent

respectively). Other heavy losers, with the percentage decline between the maximum population and 1940 are Franklin 29, Spencer 28, Crawford 27, Clay 26, and Parke and Owen, both 25. Eleven counties lost from 25 to 40 per cent and 17 lost from 15 to 24 per cent.

The counties of especially heavy population loss (25-40 per cent) are in the southern half of the state, but the central third of the state has 12 counties which have lost from 15-40 per cent. No county in the northern quarter of the state has lost more than 14 per cent, the amount that Pulaski lost.

The counties which have lost the largest number of people between their maximum and 1940 with their losses are shaded horizontally in Figure 3. Jefferson County lost 9,829; Clay, 8,920; Spencer, 6,196; Franklin, 5,811. Counties which lost from 4,000 to 5,700 people are Parke, Switzerland, Martin, Brown and Owen. On Figure 3, losses of over 5,000 are shaded darkly, losses of 3,000-4,000 are shaded moderately, losses of 2,000-3,000 are shaded lightly, and losses less than 2,000 are unshaded. The counties which gained (had more people in 1940 than at any earlier census) are cross diagonally.

No losing county stands alone. The largest contiguous belt of declining counties extends from Benton County in the northwest, southward to the Ohio River. In this broad western zone all the counties have lost population except Tippecanoe (Lafayette), Gibson and Vanderburgh (Princeton and Evansville). Crossing the southern third of the state is another zone of counties which have lost rather heavily. Eight southern counties have, however, not lost, and four others have lost only slightly (Jackson, Lawrence, Orange and Vigo).

Several counties which lost heavily border counties which have continued to gain population. Examples are Brown, Boone, Carroll, Harrison, Jefferson, and Tipton, with losses of 17 to 40 per cent, each of which border one or more growing counties.

The counties which have lost heavily in population are of three chief types: (1) rural counties which have suffered serious loss of timber and soil resources, with the result that there are fewer farm families. Examples of this type are Switzerland, Martin, Owen, Brown, and Crawford. (2) Another type consists of excellent farming counties which have lost population as a result of smaller families, resulting from birth control, and encouraged by the increased use of labor-saving machinery and the higher standard of living desired. Examples are Benton, Tipton, Carroll, Blackford, Wells, Hamilton, and Union. (3) Formerly important coal-producing counties have also suffered a decline, with the exhaustion or abandonment of shaft mines. Examples are Clay, Vermillion, Spencer, Pike, and Sullivan.

The counties which have continued to lose population mostly lack sizable cities. Map 1 shows that three of them are on the Ohio River (Switzerland, Harrison, and Spencer). Eight others are south of the National Highway (U. S. 40) (Orange, Lawrence, Greene, Sullivan, Clay, Shelby, Rush, and Franklin). Only one northern county (Dekalb) has continuously lost, after attaining its maximum in 1900.

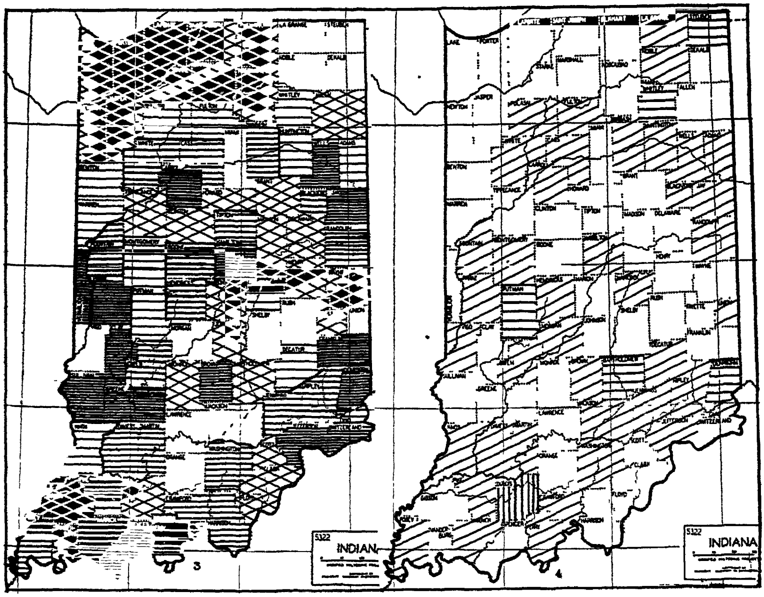

Fig. 3. Counties classified as to loss of population between maximum and 1940. The diagonally crossed counties had most people in 1940. The darkly shaded counties lost 5,000 to 9,820 people per county; the moderately shaded counties lost 3,000 to 5,000, and the lightly shaded counties lost 2,000 to 3,000. The unshaded counties had losses of less than 2,000 people per county.

Fig. 4. Census date of the minimum population following the maximum (generally attained in 1870 to 1900). Vertical shading, minimum in 1910, horizontal shading, minimum in 1920, diagonal shading, minimum in 1930. The unshaded counties had their minimum in 1940 or else have had no minimum as they have grown continuously. (These types are distinguished in Figure 1.)

In addition to the counties which had more people in 1940 than at any earlier census, crossed diagonally in Figure 3, are several counties which had almost as many people at the 1940 census as at any earlier census. They are shaded lightly in Figure 2, and are mostly unshaded in Figure 3. Nine counties had losses of less than five per cent, Vigo, Jackson, and Orange (each less than 1 per cent), Lawrence 2, Shelby 3, Adams, Cass, Dekalb, and Whitley each 4. Ten counties with losses of five to eight per cent are Huntington, Knox, Miami, Noble, and Perry (each 5), Rush and Wabash 6, Montgomery, Morgan and Putnam each 7. These 19 counties of small percentage loss, shaded lightly on Figure 2, are widely distributed over the state. However, except for Vigo and Putnam, each borders some county which has continued to gain.

Figure 4 shows by shading the census dates for the minimum population following the maximum, which had been attained in most cases in 1880 and 1890. Five of these counties recommenced gaining between 1920 and 1930 (Bartholomew, Dearborn, Putnam, Steuben, and Whitley). They are shaded horizontally in Figure 4. About one-third of the state's

counties continued to lose population until after the 1930 census, but then gained appreciably before 1940. These counties are diagonal lines in Figure 4. Eighteen counties attained their minimum population in 1940. They are horizontally lined on Figure 1. DeBois County had its minimum in 1910 and has gained steadily since then. It is shaded vertically in Figure 4.

The 58 counties that have checked their decline and had more people in 1940 than at the previous or some other recent census (unshaded in Figure 1) are most numerous relatively in the northern fourth of Indiana, where, it will be recalled, are several of the counties which have never suffered a decline in population.

The large number of Indiana counties which, after suffering a decline in population, have commenced gaining again, suggests widespread increased opportunities for earning a living. This is partly because of increased industrialization. The sharp decline in population that had taken place earlier occurred when, partly because of the increased use of farm machinery, fewer people are needed on farms. Indiana has ceased to be chiefly an agricultural state. The 1940 census recorded that less than a fourth (23.7 per cent) of Indiana's people were then on farms.

The extensive changes have taken place since 1940 in population distribution in Indiana, associated with war stimulated industrialization and army camps. Undoubtedly when the data for the 1950 census are available, some sharp changes from the trends sketched above will be revealed. Nevertheless, the present discussion helps with the understanding of recent decades, and presumably will throw light upon the changes of 1940-1950.

MATHEMATICS

Chairman: WILL E. EDINGTON, DePauw University

The MATHEMATICS SECTION met with the Indiana Section, MATHEMATICAL ASSOCIATION OF AMERICA.

Professor Paul M. Pepper, University of Notre Dame, was elected chairman of the section for 1944.

Irregularly regular polyhedra. LEON ALAOGLU and JOHN GIESE, Purdue University.—The classical regular polyhedra are generalized by considering polyhedra with all faces congruent but not necessarily regular polygons, with the same number of faces meeting at each vertex, and with two faces meeting at each edge. For finite polyhedra of genus zero (topological spheres) the Euler polyhedron formula reduces the possibilities to the usual five ranging from tetrahedron to icosahedron. Constructions using the maximum geometrically possible numbers of unequal edges are devised to show the existence of all of these five types except for the irregularly regular icosahedron with scalene triangular faces. For genus one (topological tori) the Euler formula reduces the possibilities to triangular, quadrilateral, and hexagonal faces. Constructions are devised to show the existence of the first two kinds of tori.

The elementary functions. EMIL ARTIN, Indiana University.—This paper shows how to introduce the elementary functions e^x, log x, cos x, sin x in a completely rigorous way, using only the simplest rules about limits. The proofs thus obtained cover all properties of these functions, all limit relations, and also the infinite product of sin x.

This makes it possible to have all these functions available from the beginning in a course on advanced calculus.

A method for the solution of algebraic or transcendental equations. M. GOLOMB, Purdue University.—The more common methods for determining the roots of equations have certain shortcomings. Newton's and Horner's methods apply only to real roots, while Graeffe's method applies only to algebraic equations, etc. A new method is derived from Hadamard's investigations on the singularities of functions defined by Taylor series. The symmetric functions of the zeros of smallest absolute value are given as limits of quotients of persymmetric determinants involving successive coefficients in the Maclaurin expansion for the reciprocal of the function.

Some developments in the analytic theory of continued fractions. MARION WETZEL, Indiana University.—Results contained in three recent papers: (1) E. D. Hellinger and H. S. Wall, *Contributions to the analytic theory of continued fractions and infinite matrices*, Annals of

Mathematics, vol. 44 (1943), pp. 103-127, (2) H. S. Wall and Marion Wetzel, *Contributions to the analytic theory of J-fractions*, to appear in an early issue of the Transactions of the American Mathematical Society, (3) H. S. Wall and Marion Wetzel, *Quadratic forms and convergence regions for continued fractions*, Duke Mathematical Journal, vol. 11 (March, 1944), point the way toward an *analytic theory* of continued fractions. That is, a theory in which many isolated facts may fit together in a unified structure. The unifying principle is the notion of a *positive definite J-fraction*, characterized by the fact that the J-form whose matrix is the imaginary part of the J-matrix (cf. (1)) is positive definite when the imaginary part of the variable z is positive. Included in this class of continued fractions are those of the Stieltjes theory and its later extensions, many of whose properties extend to the whole class. In addition, many new and old convergence theorems, including recent results on convergence regions, are contained in the theory of positive definite J-fractions.

PHYSICS

Chairman: O. H. SMITH, DePauw University

Mason E. Hufford, Indiana University, was elected chairman of the section for 1944.

The mathematical versus physical components of a rectified wave. D. B. GREEN, Ohio University, Athens, Ohio.—A Fourier analysis of the voltage output of a half wave rectifier gives an infinite series of harmonics. A cathode ray oscilloscope does not show any of these harmonics but only the rectified half sine wave. A wave analyzer shows that the harmonics do exist. This paper attempts to harmonize the two divergent results.

PSYCHOLOGY

Chairman: W. A. KERR, Radio Corporation of America,
Camden, New Jersey

Professor H. H. Remmers was elected chairman of the section for 1944.

The urgent need in industry for a more extensive psychological program: Some case histories. C. R. HEADLEE, Indiana University.—First is considered the scientific evaluation of the prospective employee with special emphasis on tests for intelligence, mechanical ability, sensory ability, particular requirements for the job, and emotional qualities.

NEXT will be the problems of adjustment to the new job and to new associations. With this is grouped the problems arising due to the extra stress of war-time and over-time. A number of cases observed and studied during a year as night doctor in RCA's Indianapolis plant will be presented. The psychological aspects will be stressed to illustrate the need for some form of psychological attention, even if it be in disguised form.

Lastly will be presented a number of cases of personality breakdown which occurred in the industrial situation. These cases were observed and studied while working with a practicing psychiatrist but are discussed from a psychological point of view.

An attempt will be made to show that even from a purely dollars and cents standpoint large industrial plants would benefit from the establishment of more complete psychological services. No consideration of the social values will be made.

An objective study of pain using the conditioned response technique. C. R. HEADLEE, Indiana University.—A very brief introduction to the subject of pain is presented including these factors: (1) *methods* which produce pain, with examples of thermal, electric, chemical and mechanical types of experimental pain; (2) *criteria* which indicate the presence of pain in such experimental situations; and (3) *modifications* of pain by various agents.

Wolff, Hardy and Goodell have described, and have used, a very adequate method of pain production and reporting in humans. From a strictly scientific viewpoint this work cannot be as completely objective as can animal experimentation. Neither can the scope of modifications be as great, e.g., excessive dosages of drugs, cutting of nervous centers, etc.

A valid animal experimental method would open up vast new fields for such research. The objection to the bulk of the work on experimental pain in animals is that their criterion of the pain experience is too variable, not being at all subject to quantitative or detailed description.

Pain is usually assumed as occurring with a "squeek" or with "muscular spasm."

My method combines two factors. First the standard shock-shock conditioned response technique, using dogs and modified after the Pavlovian laboratories. The second factor is the physiological fact that certain areas of the body are devoid of touch and warmth sense and present pain sensation only, to wit, the cornea, the mucous membranes of the nose, and the glans penis. The experimental conditions are:

1. One trial consists of two stimuli to the dog, which is confined in the conditioning apparatus in a soundproof room.
2. The two stimuli are:
   a. The **conditioned stimulus**, or learned stimulus, being a mild shock to the glans penis. (CS nature explained below.)
   b. The **unconditioned stimulus**, or direct stimulus, comes a second later and is a make-break DC shock to the left rear leg, just above the malleolus.
   c. Both are adjusted to a standard response.
3. One trial out of ten would be run with the conditioned stimulus (to the penis), alone being presented. By this means it is possible to learn how soon the animal makes the association, and gives the unconditioned response (leg flexion) to the learned, or conditioned stimulus alone.

Certain theoretical implications relative to the correlation of this use of the conditioning technique with the S-O-R interpretation will be discussed if time permits. W. N. Kellogg and myself have published earlier on one phase of this.

Psychological Research in Industrial Music and Plant Broadcasting.[1] W. A. KERR, RCA Victor Division, Camden, New Jersey.—Outlines seven major areas of psychological fact-finding in industrial music and plant broadcasting—(1) work place preference of job applicants and factory workers with reference to music, (2) music type attitudes of industrial workers, (3) voice type attitudes of industrial workers, (4) believed effects of music, (5) actual effects of different types of music on euphoria, morale, and specific subjective feelings, (6) effects of different types of music on the productive efficiency of workers doing various kinds of jobs, and (7) non-musical broadcast material. Research done by others is cited and several original studies are reported.

Some psychological devices of the United States Employment Service for use in the servicing of war industries. DOROTHY REECE, United States Employment Service, War Manpower Commission, Indianapolis.—Some specific contributions in the field of psychology of individual differences have been made by the Occupational Research Section of the War Manpower Commission's United States Employment Service in the develop-

[1] Address of the retiring chairman of the Psychology section. Complete article has since appeared in The Journal of Psychology, **17**, 243-61 (1944).

ment of devices to supplement the interview. Such devices are of two major types, first, proficiency tests designed to measure the degree of skill or the amount of knowledge possessed by an applicant, and, second, aptitude tests designed to measure the potentialities of the applicant. The development of these devices is keyed to the needs of industry and the public employment service offices by constant analysis of the labor market, industrial problems with which the Employment Service is concerned, and the requests for assistance from employers. In the development of both of these devices, standards for the interpretation of results are based on studies of the performance of employed workers in the occupation to which the test applies.

There are two types of proficiency tests, work-sample tests and sets of oral trade questions. The aptitude tests developed cover a large number of occupations or occupational groups. Proficiency tests have made it possible to utilize labor more effectively because the level of skill of the worker was determined prior to his referral to an employer. They also have aided in determining need for additional training by ascertaining the degree to which a worker was already skilled in an occupation. They have aided in matching the qualifications of available workers and the needs of employers with a minimum of lost time and effort.

The aptitude test batteries have been useful in instances where training was expensive, training time was excessive, and in jobs in which there was a great amount of turnover due to the inability to perform the job. They have also been used to aid employers in determining to which of several beginning jobs a worker should be assigned. The accurate placement of beginning workers decreases turnover, decreases training time, and aids in placing a more successful worker on the production line sooner.

These tools have been of value in solving selection and placement problems in various war industries. However, the field of development of psychological tools to aid in the evaluation of worker's qualifications and potentialities is one which offers vast opportunities for future research.

Measurement and evaluation of supervisory quality in industry. H. H. REMMERS and QUENTIN W. FILE, Purdue University.—Although conscious for some time of the need for careful selection and placement of workers, industry has only recently become conscious of the need for the proper use of similar techniques in the selection of its supervisory personnel. This paper deals with the development of the project whose purpose is to produce a valid test of industrial supervisory ability; with the problems and methods used in developing the experimental edition of this test, "How I Supervise"; with intended validation procedures; and with information already gained through preliminary analysis of the data obtained.

Copies of all materials will be made available to those present for discussion and comment. Special consideration will be given to the project's most difficult problem, that of securing a satisfactory criterion for validating the items of the test.

Directional Tests for Educational Guidance

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Despite the fact that many scholarly papers have been written on the general subject of "aptitudes" and "aptitude testing," there is considerable confusion as to their *functioning* in terms of different types of work or study. Part of this confusion arises because educational and vocational problems can hardly be differentiated, and part because of an overlapping of objective measures of *achievement* with those of *aptitude*. Thus, the college dean or guidance officer, influenced by the "round peg in square hole bogie" of vocational guidance, and lacking a clear conception of "educational aptitude," may prematurely emphasize the choice of a career at a time when emphasis should rather be placed upon curricular planning appropriate to the student's particular kind of readiness to learn.

As an example, we may compare "vocational aptitude" for accounting with "educational aptitude" for mathematical studies. Accountancy is an admirable profession, offering excellent opportunities for those possessing the attributes essential to success therein. Among these is at least one phase of mathematical ability. The same basic learning power, or educational aptitude in respect to dealing readily with figures and quantitative concepts, which is demanded for qualification for the C.P.A. degree, might find equal scope in other fields. Astronomy, actuarial work, statistical method, and certain operations in physical science readily come to mind. The important point is first to identify and cultivate mathematical aptitude where it exists.

The term aptitude itself is often so loosely employed that it must be here defined. The accepted use of this word among students of mental measurements is substantially that given in Warren's *Dictionary of Psychology*.[1] An aptitude is there defined as a

> "condition or set of characteristics regarded as symptomatic of an individual's ability to acquire training in some (usually specified) knowledge, skill, or set of responses such as the ability to speak a language, to produce music, etc."

Two points especially are to be noted in this definition. In the first place, aptitude is differentiated from skill. Skill is the ability to perform some given responses at a given time; aptitude is the ability to acquire skill under appropriate conditions, regardless of whether those conditions have arisen or not. In the second place, the definition does not involve any assumption as to whether aptitudes are acquired or innate even though

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[1] Warren, Howard C., ed., *Dictionary of Psychology*, Houghton-Mifflin Co., N. Y., 1934.

it is important theoretically. This usage is essentially the same as that outlined by W. V. Bingham in *Aptitudes and Aptitude Testing*.[2]

Within the field embraced by this definition, colleges and universities are more concerned as to a still more limited area, which, for convenience, may be called the area of *educational aptitudes*. Their concern is in terms of the students' abilities to acquire knowledge and skills demanded for specific curricula. Many so-called aptitude tests are at the *skill* level but the problem here is somewhat different—and much more limited—than the measurement of ability to acquire *trade skills* in clerical or factory work. For example, a report[3] in aptitude testing in the textile industry deals with the measurement of "work capacity" in that field. It involves such indices of promise for training as knot tying by hand or with a knotting machine, the visual sorting of threads, tactual sorting of fabrics, etc. These are not the kind of measures with which college deans and guidance officers are concerned.

Yet, an interesting parallel exists in methods of approach to the testing technique between primarily vocational and educational instruments. A consideration of this relation helps clear up some of the confusion over the functions of aptitude and achievement tests. We may take as analogous to *achievement* measures in education, the various "trade tests" designed to measure an individual's attained skill in a particular job, or his knowledge of operational processes. Examples of this are the type of mechanical ability test which calls for identification of tools and equipment, and the oral trade questions used by the United States Employment Service. The parallel to *educational aptitude* tests are the various instruments designed to measure the (as yet) untrained individual's *potentiality* for acquiring vocational skills. For instance, we administer finger dexterity tests to measure "teachability" or apprenticeship promise before assigning girls to vestibule school training in tube mounting operations. Aptitude tests as so conceived have been utilized more extensively by industry at the *skill level* than by colleges at the higher levels.

As far as colleges are concerned, the ultimate utilization that is made of students' aptitudes, after further training, in a particular field, is surely less important than is prompt recognition and development of this learning capacity *per se*. It is likely that vocational guidance will take care of itself in time, if intelligent planning has laid the proper foundation for personal growth and intellectual development. Narrow specialization based on specific vocational guidance is not sound. The choice of any particular occupation should not be prematurely or narrowly determined while the educative process is still in flux.

From this point of view, the present state of aptitude testing in colleges is far from adequate or helpful. Well validated achievement tests or other measures of learned materials are not of any great use as

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[2] Bingham, Walter V., *Aptitudes and Aptitude Testing*, Harper and Brothers, N. Y., 1937, p. 17.

[3] Bauer, W., "Aptitude Testing in the Textile Industry," *Industrial Psychotechnology*, **16**, 41-44 (1939).

aptitude identifiers, and they often prove misleading. Resulting data fail to suggest any promise for fields of study to which a student has not been exposed. Hence, neither the student nor the guidance officer can have a suggestion as to other fields which offer scope to intellectual powers of a different type. Achievement tests throw some light on what *he might* have acquired under other educational circumstances, or from other courses than those already experienced, but they are neither prognostic nor analytical.

A similar criticism might be applied to scholastic ability tests as measures of capacity to learn. It is assumed that scores on scholastic ability—or intelligence—tests indicate the extent of one's ability to achieve in most abstract fields. Such tests are supposed to measure abstract intelligence, but they are usually validated in terms of the language-academic curriculum with all the limitations of usefulness that such validation implies.

The difficulty in discovering valid educational aptitudes is further aggravated by factors at work in the extra-college environment. There is always the danger that some combination of primarily subjective circumstances and opinions, stemming from family or social influence, may too soon press an individual towards some course of study for which his mental make-up is not well suited. Often a girl or boy thus misdirected may not realize the presence of relative talents and limitations for a particular educational area until rather late for optimum development. In the extreme instances—which are not few—such potentialities may never be explored, with some frustration rather than fruition as the result. *There is a clear need for some kind of aptitude measurements which will discover latent learning abilities of a specialized sort*—and such abilities that might not otherwise be discovered. We need aptitude tests that have directional significance.

There is no intention here to minimize the difficulty of fulfilling this need. There is very little with which to start. Yet, research-minded educational psychologists who choose to meet the challenge will some day develop educational aptitude tests to the degree that they have intelligence and achievement tests, and will find for them equal, if not greater, acclaim in the field of education.

ZOOLOGY

Chairman: RAYMOND M. CABLE, Purdue University

Professor W. H. Headlee, Indiana University School of Medicine, was elected chairman of the section for 1944.

Studies on a new furcocercous cercaria of the Vivax type. DORCAS J. ANDERSON, Purdue University.—A new longifurcous pharyngeate cercaria of the Vivax type has been found to develop in *Campeloma sp.* collected from the Tippecanoe River. Measurements in mm. of 10 specimens killed in hot 10 per cent formalin are as follows: body length 0.386-.495 (average 0.437), width 0.172-.248 (0.205); length of tail stem 0.694-.819 (0.742), width 0.086-.106 (0.098); furcal length 0.429-.532 (0.471); oral sucker length 0.076-.093 (0.087); prepharynx 0.007-.013 (0.012) long; pharynx length 0.02-.033 (0.027). Body pyriform in outline, flattened, and spinose except posterior part of ventral surface. The tail is attached dorsally; stem and furcae spinose and with delicate hair-like processes; furcae without fin-folds. Esophagus short, intestine prominent with tortuous ceca extending to level of excretory vesicle. Excretory system typical of Vivax cercariae, the vesicle receiving two median and two lateral ascending tubules. The median tubules converge anterior to a mass of nuclei (probably the primordium of the holdfast organ) and fuse to form a single median tubule which extends anteriad to join a cross-commissure connecting the lateral pair of ascending tubules. Slightly posterior to this level, each lateral tubule receives a short common collecting tubule which divides to form an anterior and posterior collecting tubule. The excretory formula is $2[(3+3)+(3+3+3+3)]$, the last group of three flame cells on each side being in the tail stem. An Island of Cort is present. Branches of the caudal excretory tubule extend to the tips of the furcae. The cercariae develop in elongate sporocysts in the digestive gland of the snail.

The use of the factorial design for endocrine experimentation. W. R. BRENEMAN, Department of Zoology and Waterman Institute, Indiana University.—Four synthetic androgens, Testosterone (a), Testosterone-propionate (b), Dehydroandrosterone (c), and Androstenedione (d), were injected into chicks separately and in all possible combinations. The body, comb and gonad weights of the resulting sixteen series were analysed according to the factorial method of Fisher. The use of this method not only permits the analysis of the action of each hormone when given separately but makes it possible to study all possible interactions between the hormones. Statistically the method is excellent because all experimental animals are used for the calculation of standard error.

The experiments demonstated that the effects of the hormones on body weight were insignificant. Hormone b produced the greatest comb

growth followed by a, d, and c in that order. The effectiveness of b was inhibited by the presence of c and ad; c, however, gave an augmentation reaction with a and d especially the latter. With the exception of a b d the high order interactions were negative. The gonads were markedly inhibited by b, bd, and acd. Likewise significant decreases were produced by a, c, and bcd. Significant increases in gonad weights secured with bd, ab, and ac.

This method makes it possible to analyse hormone interactions with a minimum statistical error and with more uniform experimental conditions. The latter advantage is a result of the fact that the smaller number of animals used in each series permits more experiments to be seen simultaneously.

A note on the occurrence of *Sistrurus catenatus catenatus* (rafinesque), massasauga rattlesnake, in Delaware county. R. H. COOPER, Ball State Teachers College.—There has been no record kept of the occurrence of *Sistrurus catenatus catenatus* in Delaware county for, at least, the last twelve years. Hay, "The Amphibians and Reptiles of Indiana," 36th Annual Report Indiana State Board of Agriculture, 1886, states that this species belongs to the northern half of the state and asks for records of its occurrence south of Indianapolis. Hay, "The Batrachians and Reptiles of the State of Indiana," 17th Annual Report Indiana Department of Geology and Natural Resources, 1891, lists the collecting of specimens from Wabash, LaPorte, Hendricks, Hamilton, Montgomery and Marshall counties. Myers, "Notes on Indiana Amphibians and Reptiles," *Proceedings* of Indiana Academy of Science, 1926, reports a specimen from Winona Lake, Kosciusko county. Grant, "Herpetological Notes from Northern Indiana," *Proceedings* of Indiana Academy of Science, 1935, lists two specimens taken in wet ground near the Boy Scout Camp at the Dunes.

On August 6, 1937, it was reported from Gaston, Indiana, that a prairie rattlesnake was chopped into pieces when thrown into a grain separator with a bundle of oats. This report was not verified. On July 29, 1943, Claude Rakes, a farmer living about two and one-half miles north of Gaston, Delaware county, Washington township, caught a specimen of *Sistrurus c. catenatus* in his nine-acre hay field just east of the Gaston prairie. This 22-inch individual had four rattles and was kept alive at Ball State Teachers College for some time. On August 9, 1943, the same farmer caught another specimen which was 28 inches long and had eight rattles. This snake was taken as it migrated across the hard surface road in front of Mr. Rakes' house and was also brought alive to Ball State Teachers College.

West of Mr. Rakes' house there is a swamp area of about one hundred acres which was flooded much of the summer. This could be an explanation for the number of prairie rattlesnakes found in the surrounding fields. Fifteen specimens were reported from the Gaston area during 1943.

A summary of data on human intestinal parasite infections in Indiana. WILLIAM HUGH HEADLEE, Indiana University School of Medicine.—The data presented here are a summary of data obtained by various surveys

on intestinal parasite infections in Indiana conducted, during the past five years, by the writer or carried out under his supervision. One or more stool examinations were made on 2,875 individuals, all residents of Indiana, including 360 university students, 258 patients of the Indiana University Hospitals, 1,200 patients of the state hospital at Logansport, 771 patients of the state hospital at Evansville, 185 rural residents of Montgomery, Warrick and Pike counties, 63 individuals of metropolitan Evansville, 12 of Terre Haute and 26 others, most of whom were from Greater Lafayette. Each fecal specimen was examined by two methods. A fecal film was examined, and in addition a concentrate was examined, this being prepared in the earlier surveys by centrifugation, and in later studies by the zinc sulfate centrifugal flotation technique. Combining these groups, the parasites found and the percentage incidence of each were as follows: *Endamoeba histolytica*, 1.2; *Endamoeba coli*, 36.8; *Endolimax nana*, 29.5; *Iodamoeba bütschlii*, 2.6; *Giardia lamblia*, 3.2; *Chilomastix mesnili*, 2.6; *Trichomonas hominis*, 0.14; *Ascaris lumbricoides*, 0.14; *Trichuris trichiura*, 0.17; *Necator americanus*, 0.1; *Strongyloides stercoralis*, 0.9; *Enterobius vermicularis*, 3.3; *Hymenolepis nana*, 0.14; *Taenia sp.*, 0.07, and *Diphyllobothrium latum*, 0.04. Of all individuals examined, 54.1 per cent were infected with one or more species of parasites.

In addition, perianal scrapings were examined from 295 individuals to detect infections of the pinworm, *Enterobius vermicularis*. (Stools were also examined from 46 of these individuals, the data from which are included above). The N.I.H. swab was used to obtain the perianal scrapings, only one swab from each individual being examined. The groups of individuals examined by this method, and the percentage incidence of the pinworm found, were as follows: 240 patients of Riley Hospital, 16.3; 47 patients of Evansville State Hospital, 6.4; 8 others, 100.0, and for the combined groups, 16.9. If this figure were corrected on the basis of a seven-swab examination, the incidence of the pinworm would be 25.6 per cent, this figure more nearly representing the actual incidence of *Enterobius vermicularis* among those examined.

These data clearly indicate that there is considerable incidence of various intestinal parasites among persons living in this temperate region, and the physician should be aware of their presence and of the rôle that they play as etiological agents or factors of disease.

Some observations on androgen treated baby chicks. WILLIAM A. HIESTAND and DONALD E. STULLKEN, Purdue University.—In the course of a series of experiments on the effects of decompression on baby chicks it was thought worthwhile to determine the effect of androgen on anoxic survival. For this investigation a decompression apparatus described elsewhere was employed. Pressure was reduced at a fixed rate until each chick fell over backward in collapse. This "end-point" proved to be very close to death. Immediately upon reaching air it was then admitted to the decompression chamber and the bird allowed to recover. No apparent permanent damage to the chicks was seen. In all 13 male Plymouth Rock chicks were used from a flock of 24, all being hatched at

the same time. Testosterone propionate in oil was injected intramuscularly in the femoral region at the rate of 1.0 mg. twice a week for two weeks only, the total amount injected therefore being 4.0 mg. per chick. The usual androgenic effects began to appear two to three days after the first injection (7 days old) viz. enlargement and hyperemia of the comb, absence of "peeping" sounds common to baby chicks, increased pecking at the eyes of other chicks and fewer signs of fright.

When the androgen treated birds were placed in the decompression chamber and the air pressure reduced to the point of collapse very little distress seemed apparent as compared with the untreated controls, nor were the peeping sounds heard which invariably occurred with the controls. Thus the maturity influence of androgen was further demonstrated. Just before collapse the untreated chicks panted, the polypneic rate often being too fast to count visibly. In the androgen treated chicks panting was absent. Collapse in both groups occurred at about the same pressure (220 mm. Hg.) there being no apparent advantage in either group, in other words androgen did not increase hypoxic resistance.

The baby chicks definitely demonstrated the androgenic influence on social dominance (peck order) while young but after the lapse of several weeks (4 to 8) they gradually assumed a social inferiority whereupon they were dominated by the other (non-androgen treated) birds. In fact, two of the androgen treated birds were killed by the pecking of the non-treated birds. It was also apparent that the combs of the androgen treated birds had lagged far behind the development of the others, indicating the influence of (1) anti-hormonal effect or (2) a suppressed action of the gonadotropins of the anterior lobe or (3) both.

Additional observations on *Cercaria loossi* Stunkard developing in an annelid. W. E. MARTIN, DePauw University.—*Cercaria loossi* Stunkard is unique among digenetic trematodes because it uses an annelid, *Hydroides hexagonus* Bosc, as a first intermediate host. The sporocysts develop in the muscles and coelom of their host. The sporocysts and cercariae leave the annelid via definite pores that are also used as exits for the genital products of the host. The similarity of this cercaria to the cercariae of the members of the genus *Sanguinicola* strongly suggests that *Cercaria loossi* develops to adulthood in the blood of some marine fish.

Observations on a new xiphidiocercaria belonging to the Virgula group. PHILIP G. SEITNER, Purdue University.—A new cercaria of the Virgula type has been found to occur in *Goniobasis depygis* collected from McCormick's Creek, Indiana. Measurements in mm. of 10 specimens killed in hot 10 per cent formalin are as follows: Body length 0.137-.167 (average 0.149), width 0.045-.06 (0.053); tail length 0.068-.091 (0.08), width near base 0.016-.018 (0.017); length of oral sucker 0.037-.05 (0.045), width 0.038-.04 (0.039); ventral sucker diameter 0.018-.019; stylet length 0.018-.02 (0.019), maximum width (near base) from dorsal aspect 0.007; diameter of pharynx 0.01. Entire body spinose; tail simple, aspinose. Cuticle thick, with several hair-like processes near mouth. Oral sucker with large Virgula organ which is trilobed in appearance when flattened,

and orange colored when stained with neutral red. Ventral sucker at beginning of posterior body half. Prepharynx short, intestinal ceca undeveloped. Three pairs of large cephalic glands behind anterior margin of ventral sucker, not staining appreciably with neutral red; posterior pair granular; ducts a single bundle on each side with a transverse row of openings at side of stylet. Genital primordium a C-shaped mass of nuclei dorsal to ventral sucker. Excretory vesicle U-shaped, with shallow lobes, and surrounded by granular cells; main excretory tubules join arms of vesicle and divide at level of ventral sucker to form anterior and posterior collecting tubules. Develop in small, oval sporocysts in the digestive gland of the snail and encyst in ephemerid and odonatid naiads. Possibly the larva of a species of *Loxogenes.*

Anoxic survival in decompressed atmospheres of air and of oxygen. DONALD E. STULLKEN and WM. A. HIESTAND, Purdue University.—Experiments were carried out with a decompression chamber in which the atmosphere was either air or oxygen. Adult white mice, males and females of approximately the same weight (17 grams) and baby chicks, all males of the same age were exposed to gradually decreasing pressures of air or oxygen in a decompression chamber connected by way of a ballast jar to a vacuum pump. The rate of decompression amounted to a fall in barometric pressure averaging 114 mm. Hg. per minute equivalent to a rate of ascent from sea level averaging 6440 feet per minute. During decompression air or oxygen was admitted slowly into the decompression chamber by means of an inlet valve. Mice were placed in the chamber in pairs and decompressed at the above rate until dead. The barometric pressure existing in the decompression chamber at the time of death was recorded and the average of 20 such experiments determined which proved to be 158.6 mm. Hg. Following this an equivalent number of mice were exposed to decompression in an atmosphere of oxygen and the average pressure of death determined which proved to be 70.7 mm. Hg. To insure as nearly pure an atmosphere of oxygen as possible the decompression chamber was flushed out with 14 times its own volume of oxygen.

The same procedure was followed using baby chicks singly instead of pairs. The birds died at an average decompression pressure in air of 218.3 mm. Hg. and at an average pressure in oxygen of 89.5 mm. Hg.

The significance of the findings is the difference in pO_2 at death in air and in oxygen indicating a possible factor other than simple alveolar hypoxia which is the universally accepted cause of death from decompression or ascent to high altitude. Unless the pCO_2 and pH_2O of alveolar air are extremely low in mice and chicks it is difficult to imagine the results being caused by anoxia per se.

The social behavior of captive bobwhite quail, with some observations on interspecific social behavior in birds. (Motion pictures in kodachrome). HOWARD H. VOGEL, jr., Wabash College.—Several adult bobwhite quail were secured in December, 1942 from local sportsmen. A pair of these birds has been kept in captivity, in a heated greenhouse, for the

past ten months. Allelomimetic behavior (mutual imitation) is very strong in these birds. Although the birds paired in early February, no sexual mating was observed. The female showed no interest in quail eggs or in young chicks placed in the aviary. Experiments, devised to test the strength of pairing, showed this bond to be a strong one. The two birds have remained paired in all their activities. Territory played an important role in their daily behavior. The individual male studied was much more excitable, both in sounds and activity, than the female. All the quail showed a definite tendency to run back and forth along linear surfaces. The birds often formed a temporary shelter by pulling excelsior over their heads. Comparisons were made between the behavior of solitary and paired birds.

Field observations were made on bobwhite quail throughout the year, to compare the conditions in the wild with the experimental conditions in the laboratory.

Quail eggs were secured from the Indiana Department of Conservation and were incubated successfully in a small incubator as well as under a brooding hen. Motion pictures were taken of the hatching process, and the early behavior of the quail chicks was observed.

During the year the behavior of several species of birds was studied. At different intervals a starling, a pigeon, several small chicks, and a Cooper's hawk lived with the bobwhites. Several modifications of interspecific social behavior were noted. After living with the starling for a week, the quail often flew to overhead water pipes for a perch. This behavior had not been noted previously. Another interesting social group was formed by a pigeon and two chicks. The pigeon acted as a foster parent to the chicks, remained with them constantly, and even exhibited fighting behavior when quail approached "her" chicks too closely. The pigeon, although capable of flying, no longer did so except when badly frightened, but remained on the ground with the chicks. The chicks, although fairly closely related to the quail, paid little attention to those birds, seeming to prefer the quiet pigeon to the nervous, active quail.

These preliminary studies indicate marked differences and modifications in the social behavior of various species of birds.

Contributions to the osteology of the skull in various amphisbaenids.[1] RAINER ZANGERL, University of Notre Dame.—The amphisbaenids represent a strange family of reptiles which are generally considered as a heavily modified group among the lizards. An accurate, comparative study of the cranial construction in these animals revealed features, in addition to some already reported by earlier students, which leave little doubt that the amphisbaenids are neither lizards nor snakes. Some skull characters seem to indicate amphibian affinities. The amphisbaenid skull type corresponds in every essential detail to that of the Paleozoic amphibian genus Lysorophus. Future study of embryonic brain cases of amphisbaenids will in all probability reveal the real systematic position of this interesting reptile group.

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[1] Complete article in Amer. Midl. Nat. 31(2)—1944.

The Significance of Studies on the Life Histories of Animal Parasites with Special Reference to Some Digenetic Trematodes*

R. M. CABLE, Purdue University

Although animal parasites and some of the diseases they cause were recognized before the Christian era, almost all we know about their life histories has been determined since the middle of the 19th century. The first tapeworm and nematode cycles were traced in the 1850s by Küchenmeister, Leuckart, and Herbst. About this time, some very accurate surmises were made concerning the life history of digenetic trematodes. It is a little startling to read the works of Steenstrup and Moulinié with the knowledge that they were written over a generation before Leuckart and Thomas independently demonstrated for the first time the life cycle of a digenetic trematode, *Fasciola hepatica.* Although the part played by insects in the spread of certain helminth infections was demonstrated in the 1860s, the essential rôle of arthropods in the transmission of protozoan parasites was not proved until 1893 when Smith and Kilbourne demonstrated that ticks transmit the causative agent of Texas Cattle Fever. This epochal discovery was the first in a rapid series demonstrating the part played by arthropods in the spread of such important diseases as malaria, yellow fever, trypanosomiasis, bubonic plague, typhus, and dengue fever. Today, malaria alone takes a greater toll of human life and efficiency than any other infectious disease; this fact is becoming increasingly appreciated by those responsible for the health of our armed forces on battle fronts of the South Pacific and the Mediterranean. Truly it may be said that no other two decades in the history of zoology approach the years 1890 to 1910 in their contribution toward our knowledge of the causes of human suffering and mortality.

During the present century, application of the experimental method to the solution of life histories has received more and more emphasis. As a result, a great many new life cycles have been traced and hitherto obscure aspects of known cycles have been elucidated.

The most obvious and impelling reason for such studies is the control of diseases of man and the animals he has domesticated. Knowledge of the life history of a parasite reveals the point at which the cycle may be broken as a chain at its weakest link. This is an all important consideration in controlling such diseases as trichinosis and fowl coccidiosis for which effective treatments are as yet unknown. The use of knowledge gained from life history studies, then, is nothing more or less than preventive medicine.

It is generally supposed that we now know the life histories of practically every animal parasite of any consequence to the health of

* Address of the retiring chairman of the Zoology Section.

man and domestic animals. That is largely true as far as the identity and means of transmitting such parasites are concerned. There are, however, in many life cycles, important questions which have not been answered satisfactorily. For example, what becomes of the malarial sporozoite after it is injected into the blood stream by the proboscis of the mosquito? Textbook figures show it entering red blood corpuscles, directly initiating the schizogonous cycle in the circulating blood. As far as I know, no one has ever seen this happen; as a matter of fact, it is impossible to demonstrate the presence of malarial parasites in peripheral blood for a considerable time after the mosquito's bite.

One might ask—in fact, it has been asked—if studies on the life histories of parasites of lower animals are not being overdone. After all, does not every digenetic trematode, for instance, have about the same general type of life cycle including an adult stage in a vertebrate host and larvae that develop in some species of mollusk and manage to get back to the vertebrate by one means or another? Has not just about every conceivable means of such reentry been described? If, as known life histories indicate, related parasites have parallel life histories with similar hosts and similar means of getting from one host to another, why clutter the literature with further papers which contribute little more than a confirmation of this thesis? These are fair questions and ones upon which I trust the ensuing remarks may have some bearing.

Not infrequently, the understanding of the life cycle of an important human parasite has been preceded or greatly facilitated by the elucidation of the cycles of closely related forms occurring in lower animals. Ross traced the malarial cycle in birds before it was followed in man. An answer to the question already raised concerning the early stages of human malaria may be facilitated by the recent discovery of a bird malarial parasite which infects cells of the reticuloendothelial system instead of circulating blood corpuscles. This discovery may also throw much light on the mystery concerning relapses of malaria after parasites have apparently disappeared from the patient's blood stream. Thus have studies on the life cycles of parasites of lower animals implemented and supplemented our understanding of related parasites of man. Aside from the fact that lower animals are more cooperative than man as experimental subjects, studies of life cycles demonstrate that the same fundamental principles and phenomena characterize a related group of parasites regardless of their hosts. It therefore is unwise if not indeed impossible to separate medical and veterinary parasitology from the purely zoological aspects of the subject.

The fact that one or more life histories in a family of parasites may be known should not discourage further investigation of that group. The next cycle that is traced may yield some surprising and significant results as I shall show by examples taken from recent studies on the life histories of some digenetic trematodes, the group with which I happen to be the most familiar. A few introductory remarks will relieve the abrupt "jump" to these parasites.

Before many life cycles were known, the Digenea were separated into groups based necessarily on such adult characters as adhesive

organs and nature of the digestive, reproductive, and excretory systems. The adhesive organs, i.e. suckers, were used to separate the Digenea into suprafamilial categories, the monostones, holostomes, amphistomes, distomes, and gasterostomes. While this distinction still has certain usefulness, its artificiality became apparent with more precise studies of internal anatomy and has been abundantly demonstrated by life history studies. These have shown, for example, that certain monostomes are more closely related to amphistomes than to other monostomes and that some distomes are nearer holostomes than other distomes. It has even been found in one instance that the immature stage of one monostome is distomatous and that the ventral sucker degenerates as the worm becomes sexually mature. Organs of attachment, then, are interpreted as adaptations to parasitism and hence are not primitive characters providing trustworthy indications of relationships. The digestive and reproductive system likewise have been subject to profound modifications in becoming adapted to the parasitic habit and have mislead investigators in their attempts to devise a natural classification. In recent years, the excretory system has received much attention as a basis for the classification of trematodes since it would seem to be the most conservative system and therefore least altered in adaptation to parasitism. Indeed it does seem that most profound changes in the physiology of the organism would have to occur before its excretory function would be greatly altered. The flame cell arrangement is similar in related trematodes and empirical formulae have been expressed for the patterns in the various families. Yet such formulae do not consider the embryological development of the excretory bladder and its post-embryonal modifications. Furthermore, the same excretory formula may apply to more than one family and not hold for all members of the same family. It must be concluded then, that in some cases at least, distantly related adult trematodes have come to resemble one another so closely that one not familiar with their life cycles would be deceived by their mutual resemblance. Some instances suggest that this convergence may be the result of long inhabitation of the same or similar hosts. One may cite, for example, the large group of trematode parasites which occur in fishes and look so much alike that they were long believed to constitute a single family, the Allocreadiidae. While the interrelationships in this group are not yet clear, life history studies indicate that it is a heterogeneous combination of at least three distinct families.

The basis for this conclusion and for determining the relationships of trematodes in general is the fundamental zoological principle of recapitulation. Although this time-honored concept has been severely criticized in some quarters—a manifestation of the "debunking" epidemic of the twenties and thirties and no respector of either national heroes or scientific theories—there is good reason to expect that it and it alone will serve as the ultimate foundation for an enduring natural classification of the trematodes and many other parasites as well. The principle that closely related trematodes have similar hosts, embryological development and larval stages can be applied only with the aid of precise life history studies. The interpretation of larval stages must be made with

caution, however, for they as well as adults may possess misleading secondary modifications and will be shown presently.

We may now consider some examples of how the knowledge of life histories has altered our conception of certain families of digenetic trematodes. The family Acanthocolpidae was proposed to contain certain trematodes living in the intestine of marine fishes and having in common, among other characteristics, peculiar modifications of the genitalia. It has been known for several years that fish become infected with these flukes by eating other fishes containing the encysted metacercarial stage. Then Martin traced the life history of *Stephanostomum tenue* and showed that this member of the family has a rather uncommon type of cercaria which develops in a marine prosobranch snail and has a simple tail, eye-spots, and a stylet. Cercariae escape from the snail and penetrate fishes. Since this is in agreement with earlier observations on encysted stages, it seemed likely that all members of the family would have life histories quite similar to that of *Stephanostomum tenue*, i.e., have ophthalmoxiphidiocercariae which encyst in fishes. Later Dr. Hunninen and I traced the life history of *Deropristis inflata*, a charter member of the family Acanthocolpidae. To our surprise, we found that the cercaria of this species was quite different from that of *Stephanostomum* and encysted in annelids instead of fishes. Consequently, it was necessary to revise the family and transfer *Deropristis* to another where, judging from adult characters, one would never have supposed it belonged.

Another example of the misleading resemblance of adult characters is afforded by the Microphallidae, formerly included with the Heterophyidae because of the apparent similarity of their genitalia. As a matter of fact, this resemblance is superficial and there are in both groups all stages from the most modified genitalia to the generalized type characteristic of many other trematodes.

Not only may trematodes of different families possess misleadingly similar modifications of the genitalia but also two members of the same family may differ widely in this and other respects. This difference is well illustrated by the opecoelid genera *Opecoeloides* and *Podocotyle*. In *Opecoeloides*, there is no cirrus sac, a small accessory ("genital") sucker is situated on the forebody and the intestinal crura open into the excretory vesicle, the excretory pore thereby serving as an anal opening. *Podocotyle*, on the other hand, has a well developed cirrus sac but lacks the accessory sucker and connections between the digestive and excretory systems. Yet these trematodes have cercariae that are almost indistinguishable, identical excretory patterns, and exactly parallel life histories. Those not familiar with the trematodes may be surprised to learn that some members of the group possess anal openings and may be inclined to attach considerable significance to their presence. Ozaki proposed three distinct families based almost solely on the various types of these openings. However, several investigators have disagreed with this view and their opinion that anal openings in trematodes are secondary structures with no greater than generic value has been abundantly substantiated by life history and morphological studies.

One example will suffice to show that additional life history investigations in groups that have already been studied to a considerable extent may yield pertinent information concerning the relationship of one family of trematodes to others. Several studies have demonstrated that the cercarial stage of the Brachylaemidae is either tailless or possesses a very minute tail. From the number of such studies, it might be supposed that these are the only types of larvae that members of the family would possess. Allison has shown very recently, however, that one member of the family has a typical fork-tailed cercaria which is free swimming. This study indicates that in the other known brachylaemid cercariae, rudimentation and loss of the tail is associated with the suppression of a free swimming phase in the life history. The extreme of this modification is seen in *Leucochloridium* whose cercarial stage does not leave the snail at all but remains in the sporocyst which grows into the tentacles of the snail. As a result, the tentacles become enlarged and brilliantly colored, resembling caterpillars. These attract the attention of birds which pick off and eat the tentacles containing the worms, thereby becoming infected. Interesting as this life history is, the discovery of a fork-tail larva in the family is more important for it immediately suggests that the group is related to others having similar larvae. Yet had it been assumed that a knowledge of the life histories of three or four other members of the family was sufficient—that further study would be a mere repetition—this significant discovery would not have been made.

This example also illustrates the caution that must be exercised in the interpretation of larval stages. Caudal rudimentation and other secondary modifications of larval stages must be recognized for what they are. It is obvious that the more life histories we know in a group, the easier it becomes to determine with certainty the primitive or typical larval type and understand the nature and extent of secondary modifications. In several families of trematodes, there seems to have been a shortening of the life cycle with the gradual elimination of the second intermediate host which enables the parasite to get from the mollusk to the definitive vertebrate host. This tendency is illustrated by some of the microphallids. The cercaria of *Spelotrema nicolli* has a well developed tail by means of which the larva swims actively after escaping from the snail. We have found a closely related cercaria, as yet undescribed, which has a tail about half as long as that of the *Spelotrema* cercaria, and although it escapes from the snail, this larva is utterly incapable of swimming. Rothschild has found, however, that another microphallid larva develops a tail but sheds it and encysts without even leaving the snail. This species accordingly has only two hosts in the cycle, the snail and the vertebrate which becomes infected by eating the snail. Microphallid cercariae that escape from the snail, however, have a third host in the cycle, a crustacean into which the cercariae penetrate and encyst.

The above disussion has emphasized mostly the usefulness of life histories for taxonomic purposes. The broader implications of such studies should be mentioned at least. Although life history studies, if well done, include many minute details and presuppose an acquaintance

with a considerable amount of literature if effort is not to be misdirected, they are far from narrow, specialized investigations. If, for example, one undertakes tracing the life history of a digenetic trematode, consideration must be given not only to the parasite itself but also to the structure, habits, ecology and distribution of the molluscan and vertebrate hosts and very likely a second intermediate host belonging to a still different class of animals. If, as is usually the case, one begins with a knowledge of only one stage and its host, the chances are that the acquaintance of a number of animals will be made before the other hosts are determined and the cycle proved. The study of trematode life histories may be a slow way to become familiar with the fauna of a locality but I know of no method that is more interesting or demonstrates in a more impressive manner the incessant struggle for existence and impact between organisms in the web of life.

Life history studies indicate with considerable clarity that complex cycles involving two or more hosts evolved very slowly, including at first a single host to which others were added gradually, one at a time. Life history studies suggest, for example, that ancestors of the malarial *Plasmodium* and the trypanosomes first parasitized and developed fairly complex stages in invertebrates alone, possibly before the appearance of vertebrates. These ancestral parasites must have evolved along with their hosts, their descendents becoming parasites of their hosts' descendents, new species arising to parasitize new host species. With the evolution of blood sucking habits among some of these invertebrate hosts, a portion of their parasites' life cycles was bestowed upon the vertebrates which provided the blood meals. Most of the invertebrates, however, did not become blood suckers but some of these fell prey to other animals with whom they shared their parasites. Thus have sporozoans and flagellate parasites taken advantage of the habits of both predators and blood-suckers in extending their life histories to include more than one host. Some of the relatives of the ancestral *Plasmodium* and *Trypanosoma* did not take this step, however, and their descendents have remained one-host parasites until this day. It is significant that some of them have essentially the same stages in one host that their relatives have divided between two host species.

In brief, it may be stated that the study of parasite life histories is a study of the way of life practiced by the majority of living things. It is an inquiry into the manner in which they assumed that way of life, have become adapted to it, and have taken advantage of the associations and habits of other organisms. Finally, it exposes the risks inherent in the parasitic mode of life and reveals means of increasing the risks for those who by choice or necessity live at the expense of others.

Insect Pests of Cucurbit Crops in Indiana[1]

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A study of the biology and control of the striped cucumber beetle during the years 1932 to 1942 revealed the presence of many other insect pests on cucurbit crops in Indiana. While the striped cucumber beetle and the melon aphid were found to be the two most serious pests of cucumbers, cantaloupes and watermelons, and these two in addition to the squash bug and the squash borer on squash and pumpkin, 25 other insects were observed on these crops. In attempting to estimate the damage one pest does to a crop, it is necessary to know the other insects on these same plants and the extent to which their damage contributes to the total loss. In addition, it is frequently possible to direct one insecticide application at two or more insects and thereby reduce the cost of producing the crop.

In a previous publication (Gould, 1944) it was estimated that insects damage cucurbit crops in Indiana to the extent of over $525,000 annually. Most of this loss is caused by the four insects mentioned above, although other pests have contributed substantially to this total in some years. In the following discussion the 10 major pests of cucurbits have been listed according to their economic importance, while the others are occasional pests and cannot be accurately classified as to which is the more important.

1. The striped cucumber beetle, *Diabrotica vittata* (Fabr.), is the most important pest of cucurbits in Indiana. During the past 12 seasons it has been a serious pest in fields around Lafayette every year and caused from 10 to 60 per cent loss to these crops. One canning company in northern Indiana reported a 75 per cent loss of their crop in 1943 from the beetles and bacterial wilt. Damage by this insect is caused in three different ways: the feeding of the adults on seedlings and mature plants; the feeding of the larvae on the roots; and the transmission of bacterial wilt of cucurbits. The feeding of the adults upon unprotected seedlings often necessitates the replanting of fields, as the beetles migrate in about the time the plants are coming up. An even more serious type of damage results from the feeding, which usually inoculates the plants with the organism causing bacterial wilt. In this instance plants grow long enough to bloom or even produce a few fruits before the disease kills them.

The details of the life history have been worked out by the author (1944). The life history in brief is as follows: the adult beetles hibernate under leaves and other debris on south slopes of wooded hillsides. In the spring the beetles emerge and feed on a number of early blooming flowers until the cucurbits are present. Then the beetles migrate into the fields,

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where the female lays her eggs singly in the soil around the roots. Eggs hatch in about a week and the larvae feed on the roots for about two weeks before changing into pupae in the soil. After eight to 10 days in this stage the new beetles emerge and start feeding on the foliage of cucurbits. In the vicinity of Lafayette this insect has two generations a year, with the peak of the first brood beetles present around July 15, while the second brood of beetles start emerging around August 15 and continue until frost. These beetles hibernate and come out the following spring, having a life span of 10 to 11 months.

In July of 1942, a number of striped cucumber beetles were observed on squash and cucumbers in the experimental plots near Lafayette that differed from the usual striped beetle. Even in the field this new beetle could be readily distinguished from the regular form by its broader black stripes on the elytra and the yellow abdomen in place of the normal black. A series of these beetles were sent to the taxonomic division of the U. S. Bureau of Entomology and Plant Quarantine and were reported to be a new species by H. S. Barber. Mr. Barber will describe this species in the near future.

2. The melon louse or aphid, *Aphis gossypii* Glov., is a serious pest on cucumbers, cantaloupes and watermelons, but rarely attacks squash and pumpkin. This insect was present every year during this study and frequently was the cause of the early death of the crop. The aphid population normally built up slowly during the early part of the summer, but around the first of August was usually sufficiently large to kill some plants. In some seasons aphids were held in check by parasites and predators, especially by ladybird beetles (Coccinellidae) and their larvae and by the larvae of lace-wing flies (Chrysopidae). The feeding of plant lice caused a typical curling of the leaves, which protected the insects from insecticide applications. Heavily infested areas in fields were easily detected as a black mold developed on the sweetened secretions of the aphids.

In studies on the control of the cucumber beetle it was found that plots treated with certain insecticide mixtures had a larger aphid population than untreated areas. The most serious aphid population was found on plots treated with calcium arsenate, as they appeared there first and seemed to develop in destructive numbers earliest. In a normal season the first aphid infestations were noticed about the time the plants were starting to vine and gradually increased until many plants were dying after about the second or third week of harvest. Observations over a period of years showed the following intensity of aphid damage from heaviest to lightest on plots treated with the various mixtures:

1. Calcium arsenate dust
2. Bordeaux-calcium arsenate spray
3. Cryolite dust
4. No treatment
5. Rotenone dust

Plots treated with rotenone mixtures actually had less damage from aphids than the untreated area, but since rotenone gave poor control of

the striped cucumber beetle, it was found best to use nicotine in conjunction with one of the other treatments.

3. The squash bug, *Anasa tristis* (DeG.), was found to be an exceedingly destructive enemy of squash and pumpkin and occasionally attacked cucumbers and cantaloupe. Many reports of this pest injuring cucumbers have been received, but only in the past few years has injury been seen in the experimental plots. Damage to squash and pumpkin was caused by both nymphs and adults, which eventually killed most plants either alone or in conjunction with the squash borer. Adults hibernated in debris around the garden area and in woods and fence rows nearby. In the spring the adults appeared in June when squash were about ready to bloom. The feeding of these bugs on the plants frequently caused a wilting condition of the plants known as Anasa wilt. The females started laying clusters of brown eggs on the foliage in early July and from them the small gray nymphs emerged and started feeding. Both nymphs and adults were gregarious and often several hundred were found on a single plant. There was one generation a year of this insect.

Squash bugs and the squash borer have made it almost impossible to grow squash and pumpkins. It was difficult to say which of the two was the more destructive, as usually both contributed to the death of the plants. Examination of several bush (Zucchini) squash dying early in the summer of 1941 with Anasa wilt revealed 10 to 20 adult bugs on the lower leaves of wilting plants. Since this wilting condition occurred before nymphs were present, it was concluded that only the feeding of the adults was responsible for this damage. Plants dying later in the season had both the adults and nymphs feeding on foliage and stems as well as many borers in the base of the plants.

Damage to cucumbers was caused by the overwintering squash bugs attacking small plants with only three to eight leaves. The affected plants when first noticed resembled cucurbit wilt, except that the entire plant wilted in a period of about 24 hours. An examination of wilting plants always revealed one or more adult bugs still feeding. Squash bug eggs were found on cucumbers on only one occasion, although many nymphs, migrants from nearby squash, have been collected on cucumbers. The young apparently did not cause the disease-like condition of the plants.

The damage by the adult bugs to cucumbers was checked in the laboratory by placing one bug in a cage with a cucumber plant. At the end of 24 hours the plant was wilting and died the following day. In another cage three bugs were placed on one plant and allowed to feed one hour, when the plant showed signs of wilting. The bugs were removed and the plant recovered.

4. Squash borer, *Melittia satyriniformis* Hbn., is a serious pest of squash and pumpkin but has not been found attacking cucumbers and cantaloupes. The eggs of this lepidopterous borer were laid on the stems and leaves near the base of the plant. The young larvae upon hatching entered the stems near the ground and remained there until maturity. The large base of the squash plant was well suited to this insect, for often as many as 25 to 50 borers in all stages of development were found

in one plant. Injury from this insect could be distinguished from Anasa wilt by the dying of the ends of long runners first. The wilting symptoms of an infested plant were commonly observed on hot days and resembled the symptoms of bacterial wilt in cucumbers.

5. The 12-spotted cucumber beetle, *Diabrotica 12-punctata* (F.), has been a destructive pest of cucumbers, cantaloupe, squash, pumpkins, watermelons, and gourds in practically all seasons of this study. This insect in the adult stage was a serious pest of many plants, such as beans, turnips, tomatoes, and flowering plants, while the larval stage was confined to the roots of corn. On cucurbit crops the beetle was usually less abundant than the striped beetle but was still an important factor in the spread of bacterial wilt of cucurbits.

So far as known, this insect does not hibernate in Indiana but flies north each spring. In the fall these beetles were found abundant on golden rod and wild aster in protected locations. Searches were made several times during each winter for hibernating striped cucumber beetles, and in these searches no spotted beetles were ever found. Our first record of these beetles in the spring was about May 5, although it is usually the last of May before many can be found in the fields. Eggs were laid around the roots of corn and the first adults of this brood were observed during the last 10 days of July. Beetles were exceedingly abundant during the late summer of 1943 and caused considerable damage to pods of green beans, the silks of sweet corn, and ripening tomato fruits. On August 15, 1941, large numbers of beetles were observed destroying the foliage and fruits of ornamental gourds.

On cucumbers and related crops the calcium arsenate-insoluble copper dust mixture used against the striped cucumber beetle was found to be effective against this species, although the beetles were repelled rather than killed.

6. Pale striped flea beetle, *Systena blanda* Melsh., was a serious pest on cucurbits during several seasons of this study. This pest was exceedingly abundant early in the spring in most years but occasionally persisted until the middle of July. This beetle was found on a number of wild and cultivated host plants and usually migrated to cucurbits as soon as they were up. Feeding on the small seedlings usually resulted in their death. In 1941 some hybrid cucumbers were planted around the edge of the experimental plot and were to be left untreated for records on survival from bacterial wilt. Flea beetles became so numerous on these hybrids that they had to be dusted four times in a period of about 21 days to save them for the wilt tests. The regular cucumber beetle dust gave good control of this pest.

7. Cutworms, especially the greasy cutworm, *Argrotis ypsilon* (Rott.), were destructive to cucumber plants during several seasons. Some species of cutworms were usually present in the field when the plants came up, and a single worm frequently ate several adjacent plants in a single night. Other species of cutworms were present during the summer months but seldom damaged the plants. Losses from these pests were usually negligible, although damage was frequently found in fields which had been weedy the previous year.

8. The pickleworm, *Diaphania nitidalis* (Stoll), was first observed in the field about the first of August and attacked the maturing fruits of cucumbers, cantaloupe, squash and pumpkins. Losses from this insect, which bored into and ruined the fruits, were quite severe on those maturing late in August and in September. The female moth laid her eggs on the stems and the young larvae usually fed in the blossoms until about one-third grown, when they migrated to the fruits. The worm entered the fruit and fed on the interior in such a manner that the fruit usually rotted. The opening in the fruit was plugged with green frass by the larva. Larvae frequently migrated from fruit to fruit. Damage has been reported from the southern part of Indiana, and in seasons with a late fall losses in northern Indiana are sometimes serious.

In 1937 the worms became quite abundant in cucumbers grown for pickles in northern Indiana. Since the pickles were harvested before the fruits were mature, worms were frequently found in the fruits after processing. During that winter one canning company sent in a number of specimens of preserved worms both in and out of the pickles, as well as many pickles with holes through the center. Since the presence of the worm or its feces in the finished product constituted a violation of the pure food laws, the company was greatly concerned. During the 1938 season they hired extra help on their grading machines and offered a bonus for each worm or infested cucumber found. In checking the situation on August 24, it was found that at least 90 per cent of the 480 contract growers were bringing in wormy cucumbers. In that week the graders found over 600 wormy fruits.

Growers in northern Indiana have not attempted to control the pickleworm, since outbreaks of this pest were sporadic and could not be predicted. In addition, the worms fed inside the fruits from the time they were half grown, and so any attempt at control had to be made when the young larvae were feeding in the blossoms.

9. The horned squash bug, *Anasa armigera* (Say), is similar to the true squash bug, from which it can be distinguished by the lighter color of the abdominal margins and by the sharp spine at the base of the antennae. Its type of feeding and habits were identical to the other species, except that attacks on cucumbers were more frequently made by the horned bug. This species was seldom observed a few years ago, but now it has increased in abundance to that it is frequently the predominant form found early in the season. The egg and nymphs of this species were not observed in these studies, unless they were confused with those of *A. tristis*.

10. The garden springtail, *Bourletiella hortensis* (Fitch), is a small Collembola frequently found on vegetables in early spring. It inhabits damp soils which have considerable decaying vegetation in them. Attacks from these little pests are rather sporadic, although some damage to squash, cucumbers and cantaloupes has been observed during these studies. The insect is almost microscopic in size and when disturbed jumps and quickly disappears. In some seasons they were so numerous that they covered the leaves and gave them a blackish appearance.

11. Another springtail, *Achorntes manubiralis Tull.*, has been recorded in the north central states by Folsom as abundant and injurious in cold frames, where it caused serious damage to seedling cucumbers and melons. This insect was not observed during these studies, but probably occurs in Indiana.

12. The squash ladybird beetle, *Epilachna borealis* (Fabr.), is a common pest of squash and pumpkins in the southern states and occurs in those counties in Indiana bordering the Ohio River. No serious loss has been reported from this insect in this state, although the large colonies of hibernating beetles are frequently seen during the winter under the bark of trees.

13. The squash aphid, *Macrosiphum cucurbitate* (Midd.), has been observed on some occasions but never in serious numbers. This species is much larger than the melon aphid and can be distinguished from it by its longer legs, cornicles and antennae.

14. The potato flea beetle, *Epitrix cucumeris* (Harris), has been found on cucumbers, cantaloupes and squash on rare occasions. Although its specific name refers to the cucumber, this pest shows a decided preference for members of the solanaceous family.

15. The smartweed flea beetle, *Systena frontalis* (Fabr.), was observed feeding on cucumbers at Lafayette in 1941. The injury was slight. Many weeds, including smartweed, its common host, were growing around the cucumbers.

16. The melon worm, *Diaphania hyalinata* (Linn.), is a relative of the pickleworm and has been recorded in the northern states even less frequently than its relative. The only record of this insect in the Purdue collection is a specimen reared from squash at Lafayette in October, 1936. Damage by this insect is similar to that of the pickleworm.

17. The tarnished plant bug, *Lygus oblineatus* (Say), is a general feeder that attacks a number of wild and cultivated host plants. No serious infestation of this insect was observed on cucurbit crops, although many adults were seen on these plants in the fall. On cantaloupes this insect was frequently found feeding on the soft tissue where the stem was breaking from the ripe fruit.

18. The garden flea hopper, *Halticus citri* (Ashm.), is another general feeder found on a number of cultivated and wild plants. This small black bug was frequently seen on cucurbits, but no serious injury has been recorded.

19. The false chinch bug, *Nysius ericae* (Schill.), is a common insect in vegetable gardens, although it is usually found feeding on weeds. This insect was found on cucumbers in a number of years, but always in small numbers.

20. The leaf-footed plant bug, *Leptoglossus oppositus* Say, is listed as a pest of cucurbits, but no damage was observed in these studies.

21. Adults of the northern corn rootworm, *Diabrotica longicornis* (Say), was collected feeding on the foliage of cucumbers, squash and cantaloupe in the late summer. The larvae of this pest are restricted in their feeding to the roots of corn, while the beetles feed on a number of plants.

22. The garden webworm, *Loxostege similalis* (Guenee), has been observed feeding on the foliage of cucumbers and cantaloupe during August and September of most years of this study. In certain seasons this pest was present in large numbers on many weeds and cultivated plants. Damage from this pest to cucurbits was slight, even though many leaves were webbed by the webworm larvae.

23. The corn earworm, *Heliothis armigera* (Hbn.), was found in the fruits of cantaloupe and cucumbers on two occasions. These were both in the late fall when normal food plants were absent.

24. The yellow woolly-bear caterpillar, *Diacrisia virginica* (Fabr.), is frequently common in the fall and occasionally feeds on the fruits of cucumbers.

25. The common onion thrips, *Thrips tabaci* Lind., is a general pest and frequently feeds on cucurbit crops. It is frequently serious on cucumbers grown in greenhouses.

26. The common red spider, *Tetranychus telarius* Linn., is seldom found in serious numbers on cucurbits in the field, but, like the thrips, is frequently a serious pest in greenhouses.

27. Two stink bug, *Euschistus euschistoides* (Voll.) and *E. variolarius* (P. B.), were observed as common pests on several garden crops and were collected in considerable numbers on cantaloupes. These bugs preferred the ripe fruits and fed on the soft tissue exposed when the fruit broke loose from the stem. No damage was caused.

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Human Intestinal Parasite Infections: Further Data Primarily Concerning Indiana Residents[1]

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The data presented adds to that accumulated by the writer and his associates during the past five years, on the incidence of intestinal parasite infections among residents of Indiana (Headlee, 1937, 1939, 1940, 1942a, 1942b, 1943; Headlee and Hopp, 1940, 1943a, 1943b; Headlee, Kmecza, and Cable, 1939; Hopp, 1943; and Kmecza, 1939). Prior to these studies no valid data were available concerning the incidence of intestinal parasite infections in population groups of the state. The present note is for the purpose of recording the data from a small number of examinations, which should aid in giving a more complete picture when summarized with the data obtained in previous studies.

In order to accurately determine the incidence of intestinal parasite infections, it is necessary to make a microscopic examination of fecal material from the individuals in question, which examination will reveal the trophozoites and cysts of protozoa and the ova and larvae of helminths, when present. In this study only one stool specimen from each individual was examined, but both a fecal film and a concentrated preparation (zinc sulfate centrifugal concentration technique) were examined from each fecal specimen (Faust et al., 1939). The individuals examined included both student and non-student groups, and some of the former were not residents of Indiana.

Fecal specimens from 117 individuals were examined for intestinal protozoa and helminths. Of the 117 persons examined, 89 were residents of Indiana, 63 of these being university students enrolled at Purdue University. A total of 91 students were examined, but of this number 22 were from 13 other states, and 6 were from countries or regions outside the United States; Canal Zone, China, Iraq and Egypt. Of the foreign students, 2 Chinese were infected, one of these with *Endamoeba coli, Endolimax nana* and *Clonorchis sinensis*, and the other with *E. coli* and *Giardia lamblia*. The university students ranged in age from 18 to 52 years, most of these being in the 18 to 22 age group. In the non-university group of 26 individuals, eight were under 15 years of age. The 63 university students, residents of Indiana, were from 29 counties widely distributed over the state. The data concerning the parasites found, the incidence of these parasites and other relavent data, for the individuals that were residents of Indiana (both students and non-

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students), are presented in table I. In table 2 a comparison of the incidence of parasite infections of the Students that were residents of Indiana is made with that of non-resident students. The total incidences of parasite infections for the various groups, expressed in percentage, were as follows: university students, 37.4; university students, residents of Indiana 36.5; out-state university students, 39.3; all residents of Indiana, 36.5, and residents of Indiana that were not university students, 46.2. For the entire group of 117 individuals, the parasites found and the percentage incidence of each were as follows: *Endamoeba histolytica,* 0.86; *Endamoeba coli,* 21.4; *Endolimax nana,* 21.4; *Iodamoeba bütschlii,* 1.7; *Giardia lamblia,* 1.7; *Chilomastix mesnili,* 1.7; *Ascaris lumbricoides,* 0.85; *Necator americanus,* 0.85; *Enterobius vermicularis,* 0.85; *Hymenolepis nana,* 0.85; *Taenia sp.,* 2.6, and *Clonorchis sinensis,* 0.85. In addition, perianal scrapings were examined from 8 individuals, residents of Indiana but not university students, and all (100 per cent) were found to be positive for the pinworm, *Enterobius vermicularis.*

Conclusion

It is not wise to attempt to draw far-reaching conclusions from data involving such a small number of individuals. It can be pointed out that the more common intestinal parasite infections were found, with the exception of the flagellate, *Trichomonas hominis,* the whipworm, *Trichuris trichiura,* and *Strongyloides stercoralis.* These have been found among individuals of other groups of Indiana residents (Headlee, 1942b, and Hopp, 1943). The presence of an infection of the liver fluke, *Clonorchis sinensis,* serves to illustrate that one may find the infection of this or other parasites in individuals that are far removed from the endemic centers of the parasite. Because of the present dispersal of individuals and groups to the many parts of the globe involved in this world conflict, we may expect to be confronted with infections that are new to us when these persons return to their homes. This study concerning intestinal parasite infections, and other more extensive studies that have been completed (vide supra), serve to indicate that even now we have a considerable incidence of these parasites among residents of Indiana. The evidence now available is sufficiently clear to indicate that these parasite infections should receive considerable more attention on the part of the practitioner than they have in the past.

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TABLE I.

The Incidence of Intestinal Parasite Infections among a Group of Persons Living in Indiana

	Students in Purdue Univ.						Non-Students						Total					
	Male		Female		Total		Male		Female		Total		Male		Female		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Endamoeba histolytica							1	6.3			1	3.8	1	2.4			1	1.1
Endamoeba coli	4	15.4	7	18.9	11	17.5	3	18.8	3	30.0	6	23.1	7	16.7	10	21.3	17	19.1
Endolimax nana	5	19.2	8	21.6	13	20.6	6	37.5	2	20.0	8	30.8	11	26.2	10	21.3	21	23.6
Iodamoeba bütschlii							1	6.3			1	3.8	1	2.4			1	1.1
Giardia lamblia	1	3.8			1	1.6							1	2.4			1	1.1
Chilomastix mesnili	1	3.8			1	1.6	1	6.3			1	3.8	2	4.8			2	2.2
Ascaris							1	6.3			1	3.8	1	2.4			1	1.1
Necator							1	6.3			1	3.8	1	2.4			1	1.1
Enterobius vermicularis			1	2.7	1	1.6									1	2.1	1	1.1
Taenia sp.	1	3.8	1	2.7	2	3.2							1	2.4	1	2.1	2	2.2
Hymenolepis nana							1	6.3			1	3.8	1	2.4			1	1.1
Heterodera radicicola			1	2.7	1	1.6									1	2.1	1	1.1
Infected with Protozoa	8	30.8	12	32.4	20	31.7	7	43.8	4	40.0	11	42.3	15	35.7	16	34.0	31	34.8
Infected with Helminths	1	3.8	3	8.1	4	6.3	3	18.8			3	11.5	4	9.5	3	6.4	7	7.9
Infected with both Protozoa and Helminths			1	2.7	1	1.6	2	12.5			2	7.7	2	4.8	1	2.1	3	3.4
Total Infected	9	34.6	14	37.8	23	36.5	8	50.0	4	40.0	12	46.2	17	40.5	18	38.3	35	39.3
Total Examined	26		37		63		16		10		26		42		47		89	

TABLE II.

The Incidence of Intestinal Parasite Infections among Purdue University Students; Comparison of Students from Indiana with those from Out of State

	From the State of Indiana						From States and Countries Outside of Indiana					
	Male		Female		Total		Male		Female		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Endamoeba coli	4	15.4	7	18.9	11	17.5	6	26.1	2	40.0	8	28.6
Endolima nana	5	19.2	8	21.6	13	20.6	1	4.3	3	60.0	4	14.3
Iodamoeba bütschlii							1	4.3			1	3.6
Giardia lamblia	1	3.8			1	1.6	1	4.3			1	3.6
Chilomastix mesnili	1	3.8			1	1.6						
Enterobius vermicularis			1	2.7	1	1.6						
Taenia sp.	1	3.8	1	2.7	2	3.2	1	4.3			1	3.6
Clonorchis sinensis							1	4.3			1	3.6
Heterodera radicicola			1	2.7	1	1.6						
Infected with Protozoa	8	30.8	12	32.2	20	31.7	6	26.1	4	80.0	10	35.7
Infected with Helminths	1	3.8	3	8.1	4	6.3	2	8.7			2	7.2
Infected with both Protozoa and Helminths			1	2.7	1	1.6	1	4.3			1	3.6
Total Infected	9	34.6	14	37.8	23	36.5	7	30.4	4	80.0	11	39.3
Total Examined	26		37		63		23		5		28	

Size Variations in Tetraonchinae

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In 1936, the present author observed that specimens of *Urocleidus ferox* from Lake Senachwine at Henry, Illinois, were almost twice the size of specimens of the same species from the same host, namely, the bluegill sunfish, from Lake Decatur at Illinois. This size discrepancy of species representatives from two different latitudes stimulated the author in 1940 to compare specimens of individual species from other localities of different latitudes. Observed Illinois specimens (l. 467 micra) of *Urocleidus principalis* averaged 227 microns longer than Tennessee members (l. 240 micra) of this species and *Actinocleidus articularis* from Illinois (l. 470 micra) likewise were longer by 209 microns when compared with Tennessee representatives (l. 261 micra). Later, in 1943, comparisons between specimens of individual species from Tennessee and Florida were made and similar differences were noted. *Actinocleidus flagellatus* from Tennessee (l. 388 micra) were 119 microns longer than Florida specimens (l. 269 micra) of this species; *Urocleidus chaenobryttus* from Tennessee (l. 598 micra) similarly were longer than Florida representatives (l. 325 micra) by 273 microns; and *Urocleidus grandis* from Florida (1.395 micra) were 92 microns shorter than members of the same species from Tennessee (l. 487 micra).

In every observed case where several specimens of a given species of Tetraonchinae were obtained from different latitudes and treated similarly with reference to killing and fixation, the more northern specimens were longer. The average widths of the northerly species representatives, except in one case, were as great or greater than those for the specimens farther south. In the exception noted, the northern forms were larger as shown by a greater value obtained when the average body length was multiplied by the average body width. It was interesting to note that the north-south variation for body size did not apply to individual structures such as parts of the copulatory complex, the anchors, hooks, and bars. In many cases these structures were larger in the smaller southern specimens.

Several points may be mentioned in regard to possible explanations for these size discrepancies. In the first place, fresh-water Tetraonchinae may possess developmental thresholds sufficiently high to prevent the expression of similar mean body sizes in representatives of a given species in different latitudes. Secondly, there may be a relationship between the size of the parasites and the size of the hosts involved. Again there may be a relationship between the numbers of parasites infesting a given host and the size of the parasites, that is, the size of the parasites may vary inversely as the degree of infestation. The age of the host may be

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important or the problem of food, of which nothing is known at present, may be a determining factor.

Obviously the problem may involve a combination of environmental factors which can only be determined by further work, some of which is under way at the present time.

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The Distribution and Relative Seasonal Abundance of the Indiana Species of Agrionidae (Odonata: Zygoptera)

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In a previous paper (Montgomery, 1942) the relative seasonal abundance of the adults of the 16 species of Enallagma known from Indiana, based upon the frequency of collection during 41 years (1900-1940 inclusive) was indicated. That study is extended here to include the remaining 16 species of the family Agrionidae recorded from the state.

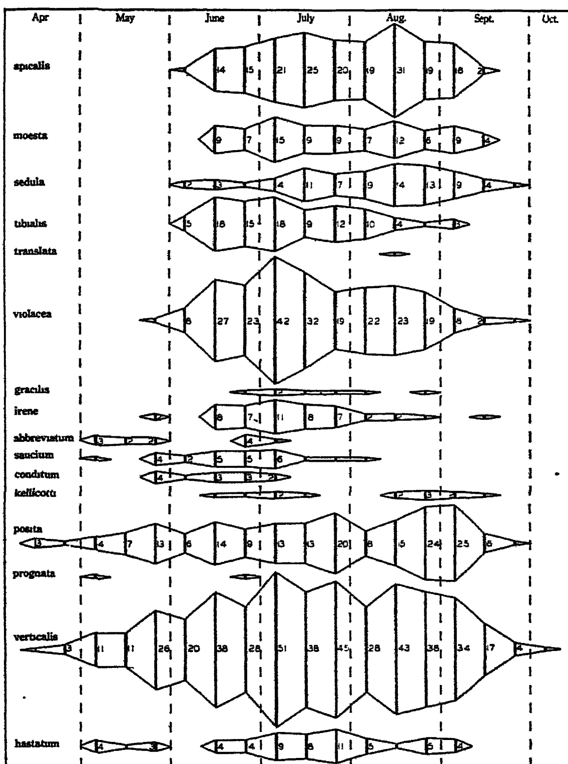

Fig. 1. The range of the flight season (or period of adult life) and the relative seasonal abundance of 16 species of Agrionidae (genera Argia, Nehalennia, Amphiagrion, Chromagrion, Ischnura and Anomalagrion) in Indiana. Collections made from 1900 to 1940 inclusive were tabulated by thirds of months and the graphs constructed from the resulting frequency distributions. Numbers near each bar indicate the number of collections of each species in each third of a month; where no number is given the number of collections is one.

Records of almost all Odonata collected or observed in Indiana since 1900 have been preserved in the note books of the late E. B. Williamson and of the author. The records for the species of the genera Argia, Nehalennia, Amphiagrion, Chromagrion, Ischnura, and Anomalagrion have been tabulated and the accompanying chart (Figure 1) indicates the relative abundance of the different species throughout the season of adult flight. As this study applies only to adults, all references to seasonal range and abundance in this paper refer to the period of adult flight.

The records of captures (or observations) were tabulated by thirds of months and the time-frequency graph for each species was constructed by plotting the frequency for each third at the midpoint (5th, 15th and 25th of the month, respectively) of the third of the time axis.

The records are based upon collections and observations from 1900 to 1940 inclusive, almost all of which have been published (Williamson, 1917 and 1920; Montgomery, 1925-1941). During the present season (1943) later records have been obtained for *Argia violacea* (Oct. 7), *Ischnura posita* (Oct. 10 and 20) and *I. verticalis* (Oct. 10 and 20). However, all records since 1940 were excluded from the tabulations to make the chart showing relative abundance directly comparable with the one in the study of the species of Enallagma (Montgomery, 1942). There are no records for 1923 and no species is listed for all of the other years, although both *Argia violacea* and *Ischnura verticalis* are recorded for 39 years. The number of years for which each species has been recorded is indicated immediately following the species name in the list below.

List of species with notes on distribution and an indication of the number of years each species was collected from 1900 to 1940 inclusive

Argia apicalis (Say)—33. Eastern states from Texas and North Dakota to Florida and New York, but has not been found in Canada except in southern Ontario and is not known from New Engand.

A. moesta (Hagen)—26. From eastern Canada into Mexico, although not recorded from western Canada and the northwestern states. However, the forms from the northeastern and the southwestern portions of the range differ considerably in coloration and frequently have been considered as separate species, subspecies or varieties. Williamson (1912) studied a rather limited amount of material from several localities from Ontario and Maine to Texas and concluded that *putrida* (Hagen) is a synonym of *moesta*. However, his study showed some geographical differentiation and it is probable that two (or more) subdivisions of the species exist. The eastern form includes that portion of the range from Texas and Oklahoma northeastward.

A. sedula (Hagen)—24. Ontario, eastern half of the United States, southwestern states to the Pacific coast and northern states of Mexico.

A. tibialis (Rambur)—30. Southern Ontario and eastern United States from Texas and Minnesota to the Atlantic coast, except New England.

A. translata Hagen—1. From Connecticut and North Carolina southwest to Oklahoma and Texas, through Mexico and Central America into South America at least as far as Ecuador.

A. violacea (Hagen)—39. From the Maritime Provinces and the Carolinas to Minnesota and Arizona.

Nehalennia gracilis Morse—4. Eastern states, Missouri to New Brunswick and Florida.

N. irene Hagen—24. Eastern states, Iowa and South Carolina northward into Canada, transcontinental in southern Canada.

Amphiagrion abbreviatum (Selys)—7. United States and southern Canada west of the Mississippi, and eastward at least to Indiana.

A. saucium (Burmeister)—16. Eastern states from Indiana to Quebec and South Carolina.

Chromagrion conditum (Hagen)—9. Northeastern states; east of the Mississippi River from South Carolina and Tennessee to Ontario, Quebec and New Brunswick, known only from Missouri west of the Mississippi.

Ischnura kellicotti Williamson—9. Oklahoma and Iowa to Maine and South Carolina.

I. posita (Hagen)—32. Eastern United States as far west as Oklahoma and Iowa, also Quebec and Nova Scotia.

I. prognata (Hagen)—2. Indiana and Ohio southeastward to Florida.

I. verticalis (Say)—39. Maritime Provinces and South Carolina to Manitoba and Oklahoma.

Anomalagrion hastatum (Say)—19. From Maine, Ontario and Iowa southward through the West Indies, Mexico and Central America to Venezuela and the Galapagos Islands.

Kennedy (1928) pointed out relations between zoogeographical distribution and evolutionary level and between seasonal distribution (of adults) and evolutionary level of anisopterous dragonflies. The data for the study of seasonal distribution were taken directly from Williamson's Indiana records, although only those to 1916, published in the annotated list of 1917 (Williamson, 1917), were used. Kennedy showed seasonal distribution by simple bar graphs, giving no indication of relative seasonal abundance, although he indicated a probable middle of the flying season for each species. He did not include any study of possible relations between the seasonal and geographical distributions of the Indiana species.

Relations between the geographical distribution and the seasonal abundance (or occurrence) of the Indiana species of Enallagma were

indicated by Montgomery (1942). Only the faintest traces of any such relations are evident on an intrageneric level among the species included in the present study. Genera included here are either small or have a small number of species (occurring in Indiana) with similar geographical ranges.

Chromagrion and Anomalagrion are monotypical genera. *C. conditum* has a rather short seasonal range in Indiana, late May to early July, and a limited geographic range in northeastern America. *A. hastatum* has a comparatively long seasonal range, early May to early September, and a very extensive geographical range (for a species of Odonata), from Maine and Ontario to the Galapagos Islands. *Hastatum* is frequently exceedingly abundant, but as it is local in distribution the rather narrow graph is probably a true representation of its total relative abundance (as compared with the sometimes locally less numerous but more generally occurring *Ischnura posita* and *I. verticalis* for example).

Amphiagrion is a North American genus ranging across the continent in southern Canada and the United States as far south as South Carolina in the east and the southwestern border states in the west. (South American species described in this genus are now generally recognized as being generically distinct from the North American forms.) Although the eastern and western forms were described as separate species many authors have considered *abbreviatum*, the western form, as a synonym of a variety of *saucium*, the eastern form. For this reason records in the literature cannot be properly assigned. All specimens of Amphiagrion taken in northwestern Indiana (Fountain, Tippecanoe and Carroll counties and northward) are *abbreviatum*, those from elsewhere in the state *saucium*. It is reasonable to assume that *abbreviatum* ranges westward from Indiana, *saucium* eastward, although a thorough study may reveal some overlapping or irregularities, or even more than two species. Both species are early summer forms, from May to July or August.

Nehalennia is a genus of about eight species, mostly Holarctic, although one species (*selysi* Kirby) was described from Brazil. Of the seven Holarctic species, three are found in the old world, four in the new. Of the old world species one (*speciosa* (Charpentier)) extends across Eurasia from Belgium and the Netherlands to Japan, one (*atrinuchalis* Selys) is known from Shanghai, and the other (*arakawai* Matsumura) was described from Japan. The four American species are primarily eastern, although *irene* is transcontinental in southern Canada; the two species not found in Indiana are limited to the Atlantic coastal area—*integricollis Calvert*, New Jersey to Florida, and *pallidula* Calvert, Florida. American species of Nehalennia inhabit bog and swamp areas, and are generally quite rare, although *irene* has been found very abundant locally in Iowa by the author. *Irene* has been taken throughout most of the season of usual adult odonate occurrence, and may be said to be somewhat "common" from mid-June through July; *gracilis* is always rare.

Argia and Ischnura are both large genera, each with more than 100 nominal species; allowing for synonyms and subspecific forms each prob-

ably contains more than the approximately 70 valid species in Enallagma (Montgomery, 1942).

Ischnura is cosmopolitan with 16 new world species, of which 12 are North American, three South American, and one (*ramburii* Selys) is found from Ontario and New England to Paraguay. In contrast to Enallagma, of which almost five-sixths (26 of 33) of the species occurring north of Mexico are eastern, Ischnura is mainly western; of 12 species occurring north of Mexico only five are found east of the Mississippi River. *Prognata* and *kellicotti* have been taken too infrequently in Indiana to furnish much information on any seasonal variation in their abundance. *Prognata* is probably not a permanent resident of Indiana, which is the northwestern borderland of its range, invaded only at intervals of favorable climatic conditions. *Kellicotti* is a species of rather strict habitat requirements—"found only about the beds of white water-lilies, resting on the floating leaves" (Williamson, 1900). On the other hand *posita* and *verticalis* are not limited in Indiana by such strict habitat requirements or borderland climatic conditions. They are among the most common and have almost the longest season of adult flight of any of the species of Odonata in the state. Although *verticalis* is probably the more abundant of the two species everywhere in Indiana, *posita* becomes relatively more abundant from north to south, a reflection of its distribution which extends several hundred miles farther south than than of *verticalis*. The three peaks of abundance so prominent in the seasonal distribution of the species of Enallagma and recognized in that of the species of Argia, are not evident in the graphs for these species. However, there is a regular alternation of peaks and valleys in the abundance of *verticalis* and, with slight irregularities and to a somewhat lesser degree, of *posita* and *Anomalagrion hastatum* from mid-May to early September. No explanation can be given at this time for these regular oscillations in abundance, almost perfectly correlated in the three species.

Argia is a New World genus, distributed from southern Canada (eight species) to Argentina (three species). A few non-American species have been described in this genus but all of them are probably misplaced either generically or geographically. Gloyd (1941) has shown that species formerly ascribed to the Kurile Islands and the Cape of Good Hope were based upon specimens from California and the Lesser Antilles, respectively. A rough estimate of the distribution of the genus was obtained by dividing its range into seven regions and tabulating the number of the 124 nominal species, subspecies and varieties of the genus recorded for each. (No attempt was made to work the synonymy of all names, but those generally recognized as synonyms were excluded from separate consideration. The division of the range into seven regions is based upon convenience and may not be well correlated with any definite climatic divisions.) In the following list the regions are arranged from north to south, and for each are indicated the total number of species recorded, the number indigenous, and the number ranging southward from the particular region to each of the more southern regions:

I. Eastern United States and Canada (to the Dakotas, Oklahoma and Texas)—total-8, indigenous-5, ranging to region II-1, region III-1, and region VI-1.

II. Western United States and Canada—total-16, indigenous-6, ranging to region III-6, and region IV-1.

III. Mexico—total-36, indigenous-15, ranging to region IV-4, region V-5, and region VI-3.

IV. Central America, including Panama—total-28, indigenous-9, ranging to region V-4, and region VI-1.

V. Colombia, Venezuela, Guiana, Trinidad and the Lesser Antilles—total-34, indigenous-22, ranging to region VI-1.

VI. Ecuador, Peru, Bolivia, Brazil and Paraguay—total-42, indigenous-34, and ranging to region VII-1.

VII. Uruguay and Argentina—total-4, indigenous-3.

In Canada and the northern United States the group is very rare or entirely absent in the central plains area. All of the six species found in Indiana have been recorded from Ontario (mostly from the southern portion only), and two occur in the Maritime Provinces. Of the other two species, one (*bipunctulata* (Hagen)) extends northward in the Atlantic coastal area as far as New York and the other (*fumipennis* (Burmeister)) was once recorded from Kentucky. In the west two species range into Canada—*vivida* Hagen which occurs southward to Mexico and eastward to Missouri is known from British Columbia and Alberta, and *emma* Kennedy has been found from California and Nevada to British Columbia.

The seasonal distribution of the Indiana species is, no doubt, a reflection of the tropical origin and essential character of the genus. Only one of the five common species has been taken before June, but most of them reach almost full abundance soon after their first appearance. The season of the several species in Ontario (Walker, 1941) is well within the plotted seasonal range for Indiana, except *moesta* was once found very numerous ("thousands of tenerals were flying in the river valley" at Erindale near Grand Forks) June 7 and the single record for *translata* was along the Thames River near Chatham on June 25. Three peaks of abundance almost identical with those found in the species of Enallagma may be noted. The first, more or less discernible in all five of the common species, occurs in mid-June, soon after the initial appearance of the species, the second appears in early July for three species (*moesta, tibialis* and *violacea*) but in mid-July for the other two (*apicalis* and *sedula*), the third apparent in all of these except *tibialis* is in mid-August which is the date of our only record of *translata*.

Although the species treated in this study are too scattered to illustrate more than traces of the correlations between seasonal abundance or occurrence and geographical distribution noted to a limited extent among the Indiana species of Enallagma, a few such relations on a generic level seem to exist.

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An Improved Method for the Determination of the Lethal Temperature of Insects, with Especial Reference to Studies on Periplaneta americana

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Published data upon the lethal temperatures of poikilothermic animals show considerable variation both as to the results obtained and the methods employed. The two main reasons for these discrepancies are the absence of a standard procedure, and the neglect of several internal and environmental factors that may affect the lethal temperature. The author has attempted to deal with these two aspects of the problem. First, an apparatus has been constructed which permits a uniform increase in environmental temperature until the lethal point is reached. Second, the effect of several internal and environmental factors upon the lethal temperature of the cockroach, *Periplaneta americana* has been studied.

In the construction of the apparatus, an ordinary aquarium insulated with fiber board is used as a water-bath. The water is stirred constantly, and is heated by two 75 watt light bulbs. The lethal chamber consists of a 250 ml. Erlenmeyer flask immersed in the water and provided with a three-hole rubber stopper through which is inserted a sensitive thermometer, and the air inlet and outlet tubes. The circulating air is first passed through seven feet of coiled glass tubing immersed in the water. This preheats the environmental air to exactly the temperature of the bath, thus preventing local overheating of the insect. The "lethal temperature" is taken as the lowest temperature at which the last member of a homogeneous group of insects dies after exposure to a uniform temperature rise of one degree every five minutes starting at the normal environmental temperature. Heretofore the lethal point has been expressed in terms of a given survival time at a constant temperature. This suffers from the disadvantage that two variables are involved. In the improved method, however, with a uniform temperature rise of one degree every five minutes, the lethal point can be expressed in terms of temperature alone. Data are thus easily compared in terms of this one variable.

The internal and environmental variables were controlled closely in *Periplaneta* by the use of a laboratory colony of roaches. Members of the same egg-sac were used as controls for the study of various factors affecting the lethal temperature. The following results have been obtained under a temperature rise of one degree every five minutes:

1. Roaches hatched from the same egg-sac and reared in the laboratory all die within a range of 0.3° C., regardless of their age. Roaches captured at random show a wider variation.

2. At 100% relative humidity, the logarithm of the weight of *Periplaneta americana* gives a hyperbolic curve when plotted against the lethal temperature e.g. at a weight of 0.003 gm. the L. T. is 48° C., whereas at a weight of 0.04 gm. the L. T. is 51° C.
3. A low relative humidity decreases the L. T. of very young roaches, but has no such effect upon older specimens.
4. The lethal temperature of all insects tested was within the range 45-55° C.
5. Starvation, injury and poisons decrease the L. T. of all types of insects.
6. The L. T. of grasshopper nymphs is 53° C. as compared to only 48.5° C. for cricket nymphs of corresponding weight and environment.

Social Behavior, Range and Territoriality in Domestic Mice

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Recent advances in biosociology have emphasized the fact that the tendency for an animal to stay in one particular locality is directly connected with the social behavior and organization of the species. In the case of birds, fighting appears to be one of the major factors which causes the division of breeding territory and limits the density of population in the species. It is in this latter connection that territory appears to have its greatest significance, as a determinant of the numbers and dispersion of a species.

In the case of the house mouse the density of population may become an important commercial problem as well as an interesting theoretical one (Elton, 1942). The following observations concerning territoriality in domestic strains were made partly in large pens where the mice were left as undisturbed as possible, and partly in connection with experimental situations involving fighting and social dominance, whose result has been reported elsewhere (Scott, 1943). While the behavior of domestic and wild mice is not identical, it was expected that the behavior of one would throw some light on that of the other.

Materials and Methods. The mice used came from two inbred stocks, the C-57 black, subline 10, and the C3H agouti. Both strains are very nearly genetically pure, and there is a high degree of resemblance between individuals in the same strain, both in appearance and behavior, provided they have been raised in the same environment. At the Jackson Laboratory at which these mice were originally studied (Scott, 1942) there is a decided difference between the fighting behavior of the males in the two strains.

The ordinary small breeding boxes do not give much scope for behavior, and mice were put into two multiple escape pens of the type illustrated in the figure. These are 5 feet in greatest diameter, and in a later experiment a side alley 10 feet long with two additional nest boxes was added. The mice roamed through all parts almost immediately, indicating that the limit of wandering had not been reached.

The pens were kept in a cellar in which there was very little light and whose temperature stayed fairly constant between 70 and 80 degrees F. except in the cold winter months, when it usually stayed between 60 and 70. An attempt was made to reverse the day-night cycle of behavior by lighting each pen with a 75 Watt lamp for 8 hours during the night, the light being turned on again for observations some time during the day. Observations extended from November 21 to May 14 in one series, and from March 8 to July 15 in the other. In each series a single pair of young mice was put into a pen, a second pair saved from the first litter, and all other young mice removed before 30 days of age. Bedding

of cotton and excelsior was provided in each nest box, together with a small amount of sawdust, and a constant supply of feed and water was kept in the center box. The pens were not cleaned out during the entire period of observations.

Behavior, the conditions of nests, and the position of mice in the pens were especially noted.

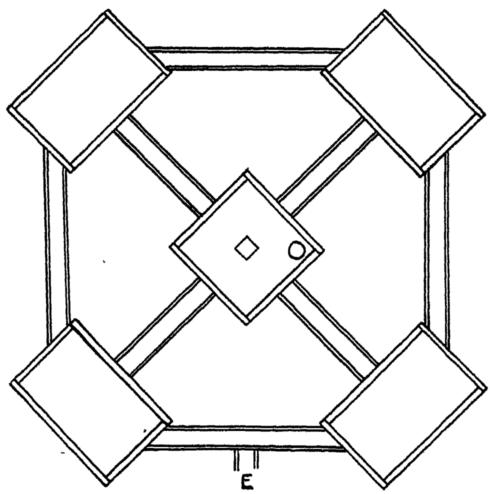

Fig. 1. Plan of multiple escape pen. At the start of the observations equal amounts of bedding were placed in the corner boxes, the center box containing a food hopper and water bottle. E indicates the spot at which an extension was attached in the second series of observations.

Effects of Changes in the Physical Environment. An attempt was made to keep the physical environment as constant as possible, so that all behavior might be attributed to changes in the social milieu. However, this was not entirely successful. A lowering of temperature was accompanied by greater general activity and seems to have been a contributing cause of one fight which got started in the longer series of observations. Such a change was also followed by a period in which solid, well-roofed nests were built and passages from them plugged with debris.

The change from dark to light was also followed by a period of greater activity, mostly investigation.

Effects of Changes in the Biological Environment. In the second series of observations one pen became infested with lice, with a consequent increase in the amount of grooming and scratching.

Under the conditions described, the observer also acted as a stimulus. The reactions varied from running away through investigation and even attempted attack. (One old male mouse came regularly to the part of the cage nearest the observer and ran up and down, occasionally stopping to bite on the wire.)

Classification of Reactions Observed. The following sorts of behavior are listed in order of greatest frequency.

Investigation. This appears to be the predominant type of behavior in the mouse. Anything new in the physical, biological or social environment is immediately investigated, chiefly with the nose and whiskers, but also with the eyes and ears. A typical bit of behavior is for a mouse to creep slowly down a new passage, sniffing and feeling every inch of the way, and occasionally running back to familiar ground. Once this is done he may dash back through it at top speed, if frightened. The reaction to a new mouse is to smell it all over, including the genital region.

Epimeletic Behavior. This type of behavior, consisting principally of the care of others, is next most commonly observed. It includes grooming, nest-building and digging, and nursing the young. As a social reaction it is most prominent in pregnant and lactating females, which build nests for the young and spend much time in grooming them. Male mice usually build nests and groom themselves in a solitary fashion but have been observed to groom other adults of either sex, especially in the C-57 stock.

Because of the construction of the pens, digging was infrequently observed.

Feeding of other animals is confined to nursing the young. No cases of carrying or hoarding food were seen, in spite of the fact that it was provided in convenient small pellets.

Eating. This type of behavior occurs at fairly frequent intervals. As a social reaction it is important to the young mice before weaning.

Shelter-seeking. Under the conditions described, mice show two forms of this behavior: attempts to get into dark spots when frightened, and attempts to get warm. Either may result in aggregation and thus become a variety of social behavior.

Sexual behavior. Inasmuch as the female mouse comes into heat only once in every 5 days and not at all during pregnancy, sexual behavior of the female was not frequently observed. In the male it was more common, usually expressed as a tendency to nose the genital region of other mice, and to follow the females. Greater activity was seen only when females were in heat.

Fighting. Infrequent cases of fighting between the adult males were seen, these being more violent in the observations carried on in the winter. Small amounts of aggression were also seen in C3H females, directed at males and young which had been weaned.

Et-epimeletic Behavior. This type of behavior, defined as calling or signalling for epimeletic behavior, is of importance only to the small mice in the nest, from which squeaks are often heard. The squeaking of adult mice when hurt may be a form of this behavior.

Allelomimetic Behavior. No indication of any sort of imitation was observed.

Range and Territoriality. In cold weather a female mouse constructs a solidly built and roofed-over nest a short time before her young are born. During the first few days she spends a great deal of time in the nest, suckling and grooming the young. If she is disturbed, squeaks are heard in the nest. In unusual cases she may move them to a different nest, carrying them in her mouth. The young mice may occasionally leave the nest as early as fifteen days, and by twenty days they are usually found scattered around the pen, while the nest is flattened and in bad repair. However, they tend to return to it for a few days. Since the female may have become pregnant immediately after giving birth, a new litter may be born about this time. She usually builds a new nest in a different part of the pen.

The males have never been seen in nests with very young litters. They are likely to join the litter about the time the nest begins to break down, and when the nests are open, as in warm weather, the male has been seen with the young as early as eight days. Males are also seen huddled together, either in nests or out of them, sleeping and occasionally grooming themselves or each other. A male and female will usually form this type of group up till the time the young are born, and the same thing may be observed between two females or among immature mice.

While the female is in estrus, a male and female keep in close contact, running around a great deal as well as showing actual sexual behavior. When the female is not in heat she shows little response to the male, and he usually reacts only with a slight sniff in passing.

Thus in the large multiple escape pens range appears to be directly connected with the nests. In the vast majority of cases, mice when first observed were found either in nests or in the boxes which contained nests. This was even more true of the females than the males, presumably because of the attraction of the young. For example, in one series of 60 observations, the female was found either in the nest or in the same box 54 times, while the male was found 50 times. The male was found 5 times in the box containing feed, and the female only once. During most of this period there were nests in three out of the seven boxes and it is unlikely that the other four boxes would be avoided so many times merely by chance. But even within such a pen, nests are frequently changed. The females usually move when bearing a new litter, and nests are rebuilt and moved with fluctuations in temperature.

When experiments on fighting were performed in the pens a different set of factors was introduced. The passages were blocked off, and two males were isolated in adjoining pens with nesting material for at least a week while being trained to fight. When the passage between the two pens was opened the mice investigated it and the other pen, usually within less than five minutes. As soon as the fight started both mice would rush through both pens at top speed, the mouse which had investigated it only once running as efficiently as the one which had known it for a week. A mouse apparently becomes familiar with a new passage after one thorough investigation, and it may be concluded that familiarity and habit are of little importance in determining the range of mice.

Fighting itself is apparently an unimportant factor, even in the division of territory. Mice have never been seen fighting for the possession of a nest, although a beaten mouse may hide in one. Female mice may fight to keep the males out of nests where there are young, but this has not been actually observed. In situations where two males are kept in adjoining pens and taught to fight (Scott, 1943) the combat usually starts when one mouse finds the way blocked to its own pen, or after one mouse has made a sexual attempt on another, and not when a strange mouse enters the pen. Furthermore, males which habitually fight each other have been found sleeping in the same nest, or huddled together in the same box.

A distinction has been made by Burt between range, which includes the area over which a given animal may roam, and territory, which may be defined as a range occupied only by a particular individual or group. In order to have range, there must be the sort of behavior which will cause an animal to remain in a particular locality. In the mouse, a combination of epimeletic, et-epimeletic and shelter-seeking behavior has this effect, resulting in the group of a female and her young occupying a definite nest. Epimeletic behavior and shelter-seeking are also present in the males, though in a different degree, and lead to the same result. However, neither of these types of behavior are constantly present, and both investigation and fighting have a definitely dispersive effect, so that range in the mouse appears to be a temporary and variable affair.

This in itself would make any stable division of territory impossible. In addition, the strong tendency toward investigation makes division of territory on the basis of familiarity and habit impossible, leaving only fighting as a basis for such division, and there are at least two possible reasons why the latter does not give a clear result. There appears to be no tendency to fight over the nests, which are the most definite spots in the range, and since mice are nocturnal, it would be impossible for a mouse to effectively patrol a territory as large as that which investigation apparently leads them to cover. Fighting in the mouse leads more to simple dispersion than to division of territory. It may be concluded that territory in mice is either temporary and variable as in the case of the nest of the lactating female, or, if it exists at all in males, extremely nebulous.

Probable Organization in Wild Mice. The differences between the C3H and C-57 strains appear to be matters of degree rather than of fundamental type of social behavior. Similarly, the few wild mice observed in this laboratory seem to differ from the domestic strains chiefly in degree of activity or "wildness," especially in those reactions involving fighting or escape. One female killed two domestic males before it was finally mated to a third.

Assuming that wild mice possess the same types of social behavior as the domestic strains but intensified, and allowing for the possibilities of digging holes, of wandering unrestrained by artificial barriers, and the presence of a fluctuating food supply, the following conclusions regarding the probable territorial organization of wild mice may be drawn.

In temperate climates a sharp difference between summer and winter behavior would be expected. In the winter mice would tend to collect in heated buildings where food is stored, showing a greater tendency toward the formation of shelter-seeking aggregations in the nests. In summer they would occupy a far wider range because of the dispersive effects of investigation, fighting and a more plentiful and widely distributed food supply.

As to territory, the heated building would form a boundary limiting the favorable environment during the winter, a situation comparable to the experimental one described above. Given an unlimited supply of food, such a building would probably contain a large number of mice before the winter was over, though the numbers might be somewhat checked by fighting between the males and by the limits of available nesting sites.

In the summer the bounds of the range would be fixed only by fatigue and distance from the food and nests. As in the tame animals such ranges could not be effectively patrolled as territories, even if mice showed such tendencies. However, chance encounters would probably result in fights, with the losers tending to retreat into familiar areas. It would be expected that such "territories" would be large, overlapping, and constantly shifting, and that the territories of females would be smaller and less rapidly shifting, because of the attraction of the young.

One may think of mouse society as a whole as thinly dispersed and fluid, tending always to spread out and cover all suitable ranges, but occasionally accumulating in small groups around the nests, the most permanent being those of a mother and offspring. The division of territory is considerably less definite than that shown by some other vertebrates. This picture corresponds fairly accurately to that obtained by Burt (1940) from his trapping data of wild *Peromyscus* which have somewhat similar behavior to that of the house mouse.

In summary it may be said that while mice show intermittent tendencies to stick to one range including a nest or nests, they probably show very little tendency to divide the total range into definite territories.

Discussion

As mentioned in the introduction of this paper, territoriality is most important as a factor regulating the density of population. Considering the fluctuating range and the lack of definite territoriality in the domestic mouse, it may be concluded that the species has no regular social means of limiting numbers, and this is borne out by the accounts of epidemics and plagues of wild *Mus musculus* cited by Elton (1942).

This in turn has a bearing on the problem of mouse control. The mouse has such a low degree of social organization and interdependence that it is impossible to adversely affect the welfare of many by the destruction of a few individuals, and a single pregnant female can form the effective nucleus of a new population. Likewise, cleaning out mice from any one particular area by poison or trapping can have no perma-

nent effect; other mice will simply move in to take their place because of the dispersive effects of mouse behavior.

The observations in this paper do give one hint to the householder; mice should show more tendency to stick to one locality in cold weather than in warm, because of the cohesive effect of shelter-seeking, and if all the mice in a house are trapped or poisoned at the onset of cold weather, it is unlikely that more will return until spring. This does not apply, of course, to closely connected heated buildings.

Probably the only permanent and completely effective method of mouse control is to store all food in mouse-proof containers. Where this cannot be done they may be controlled only through constant trapping and poisoning, or by ecological means.

The natural controlling factors of mouse population appear to be chiefly ecological, consisting of disease and predators. The dispersive nature of their social behavior gives mice considerable protection against infectious disease until they accumulate in large numbers.

Either poisoning or artificial disease propagation are likely to be expensive, which throws the burden of control upon predators. If the average citizen will keep a cat (preferably a well-fed one which will not tend to bother birds) to keep down mice within his home, and will assist in the protection of small wild predators (particularly owls which are nocturnal like the mice) which will catch the mice en route from house to house, the numbers of mice may be kept down to a minimum. This is particularly important since Cable has reported that the plague flea, which may live on mice as well as rats, is now frequently found in Indiana.

Summary

1. Territoriality is chiefly important as a factor controlling population density.

2. Pairs of mice and their descendents from the C-57 and C3H strains were observed in large multiple escape pens for periods of six months and four months.

3. In order of importance, the following general types of behavior were observed: investigating, epimeletic, eating, shelter-seeking, sexual, fighting, and et-epimeletic. No form of imitation was observed.

4. Because of epimeletic and shelter-seeking behavior, the ranges of mice are closely connected with the nests.

5. Since these types of behavior appear intermittently and variably, the ranges are likewise variable.

6. Since the ranges shift frequently, fighting does not produce definite divisions of territory. No cases of fighting for the possession of nests have been observed.

7. It is concluded that the society formed by wild mice is probably fluid and dispersive in nature, with shifting ranges and unstable, badly defined territories.

8. In consequence the natural factors controlling population density should be chiefly ecological rather than social.

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INDEX

Agrionidae in Indiana, 179.
Alaoglu, Leon, 144.
Algebraic or transcendental equations, method for solution of, 144.
Allen, F. J., 116.
Amphisbaenids, osteology of skull of, 158.
Amines, identification of, 119.
Anaerobic bacteria, 30.
Anderson, Dorcas J., 153.
Androgen treated baby chicks, 155.
Animal parasites, significance of studies of life histories of, 159.
Anode polishing, 130.
Anoxic survival, 157.
Antiserum for epidemic influenza, 50.
Artin, Emil, 144.
Avogadro's number, experiment for freshmen, 116.

Bactericidins of fowl, 29.
Bacteriology abstracts, 28.
Bacteriology, Section on, 28.
Black, Homer Francis, 1.
Blanchard, William Martin, 2.
Bolanovich, Daniel J., 150.
Botany abstracts, 72.
Botany, Section on, 72.
Bowmanites, Paleozoic, 72.
Breeze, Frederick John, 3.
Breneman, W. R., 153.
Brother Raphael, 12.
Bryophytes, studies in Indiana, 96.
Butler University, Bacteriology at, 55.

Cable, R. M., 159.
Campbell, Barbara K., 117, 119.
Campbell, Kenneth N., 117, 119.
Cercaria, furcocercous of Vivax type, 153.
Cercaria loossi, in annelid, 156.
Chemistry abstracts, 116.
Chemistry, Section on, 116.
Clostridia, iron and riboflavin, 29.
Committees for 1943, v.
Cooper, R. H., 154.
Coulter, Stanley, 4.
Cross, A. T., 72.
Cuscuta, stomata in, 100.

Degering, Ed. F., 122.
Delbrück, M, 28.
DePauw University, Bacteriology at, 57.
Directional tests for educational guidance, 150.
Divisional chairmen, 1943, v; 1944, xiii.
Dorsch, Margaret, 12.

Editor and publication of Proceedings, ix.
Electron microscope and biological research, 53.
Endocrine experimentation, factorial design for, 153.
Entomologists Meeting, xiv.
Epidemic influenza vaccine and antiserum, 50.
Ervin, Robert F., 62.
Evolutionary Processes, Rates of, 14.
Executive Committee, Minutes, viii.

File, Quentin W., 149.
Fisher, Martin Luther, 6.
Fowl bactericidins, 29.
Fractions, continued, analytic theory of, 144.
Friesner, Ray C., 72.
Functions, elementary, 144.

Gangrene organisms, 30.
Gantz, E. St. Clair, 117.
General Session, Minutes, xiii.
Geology and Geography, Section on, 139.
Giese, John, 144.
Ginkgo biloba, leaf spot of, 78.
Girton, Raymond E., 73.
Golomb, M., 144.
Gould, George E., 165.
Green, D. B., 146.
Grignard reaction as applied to student preparations, 134.
Guard, A. T., 75.

Headlee, C. R., 147.
Headlee, William Hugh, 154, 172.
Herre, Albert W. C. T., 81.
Hessler, Robert, 7.
Hiestand, William A., 155, 157.
Hughes, Edward J., 117.

Immune sera for *paramecium aurelia*, 47.
Indiana, Agrionidae in, 179.
Indiana bryophytes, 96.
Indiana counties, changes in population of, 139.

Indiana crops and chemurgy, 117.
Indiana, human intestinal parasite infections in, 154, 172.
Indiana, insect pests of cucurbit crops in, 165.
Indiana lichens, 81.
Indiana plant distribution records, iv, 1943, 105.
Indiana species of Agrionidae, 179.
Indiana University, Bacteriology at, 59.
Insect pests of cucurbit crops in Indiana, 165.
Intestinal parasite infections in humans in Indiana, 154, 172.
Iron, riboflavin and clostridia, 29.

Jamieson, W. A., 28.
Junior Academy of Science, xxi.
Just, Theodor, The rates of evolutionary processes, 14.

Kerr, W. A., 148.
King, S. Joan, 117.
Kirkpatrick, Forrest H., 150.

Lethal temperature of insects, determination of, 186.
Library committee, report of, x.
Lichens known from Indiana, 81.
Liriodendron tulipifera L., development of seed of, 75.
Luria, S. E., 28.

McClung, L. S., 29, 30, 47, 59.
Marczynski, Valentine, 12.
Martin, Lillien Jane, 9.
Martin, W. E., 156.
Massasauga rattlesnake, 154.
Mathematics abstracts, 144.
Mathematics, Section on, 144.
Mathers, Frank C., 130.
Mice, domestic, social behavior, range and territoriality of, 188.
Minutes of Executive Committee, viii.
Minutes of General Session, xiii.
Mizelle, John D., 177.
Montgomery, B. Elwood, 179.
Mother Mary Verda, 12.
Mullison, Wendell R., 73.
Mushrooms, gilled, card game, 73.

Necrology, 1.
New members, xv.
Nitrogen peroxide, reactions with organic compounds, 118.
Noland, Jerre L., 186.
Notre Dame, University of, Bacteriology at, 62.

Officers for 1943, v; 1944, xiii.
Oxygen in organic compounds, detection of, 117.

Pain studied with conditioned reflex technique, 147.
Palmer, C. M., 55.
Paramecium aurelia, immune sera for, 47.
Para-methoxyphenylisothiocyanate, reagent for amines, 119.
Past officers, xvii.
Patelski, S. Joela, 119.
Periplancta americana, 186.
Physics, Section on, 146.
Plant physiology, chronological chart, 73.
Polyhedra, irregularly regular, 144.
Porter, C. L., 73, 78.
Powell, H. M., 50.
Presidential Address, 14.
Psychological program in industry, 147.
Psychological research in industrial music and plant broadcasting, 148.
Psychology abstracts, 147.
Psychology, Section on, 147.
Purdue University, Bacteriology at, 66.

Quail, social behavior of captive bobwhite, 157.
Quantitative analysis, fundamental techniques of, 117.

Rates of Evolutionary Processes, 14.
Rectified wave, physical versus mathematical components of, 146.
Reece, Dorothy, 148.
Relative electronegativity iv. Empirical rule as teaching tool, 122.
Remmers, H. H., 149.
Reyniers, James A., 62.
Riboflavin, iron and clostridia, 29.
Ricks, Robert E., 130.
Riebsomer, J. L., 118.

Saunders, Allen, 29.
Schnetzler, E. E., 29.
Scott, Dorothy L., 73, 74.
Scott, J. P., 188.
Seitner, Philip C., 156.
Shenk's woods, 72.
Spermatophytes, pollen-grain structure in classification of, 74.
Spring Meeting 1943, xiv.
Stullken, Donald E., 155, 157.
Sulfa drugs and virus, 28.
Supervisory quality in industry, measurement and evaluation in, 149.

Table of contents, iii.
Taxonomists Meeting, xiv.

Test, Louis Agassiz, 11.
Tetanus organisms, 30.
Tetraonchinae, size variations in, 177.
Tetrault, P. A., 66.
Tomato plants, nitrogen sources and mineral deficiencies, 73.
Treasurers report, ix.
Trematodes, digenetic, 159.
Trexler, Philip C., 62.
Trustee, report of Academy, viii.

United States Employment Service, psychological devices of, 148.

Vaccine for epidemic influenza, 50.
Virus and sulfa drugs, 28.
Viruses and temperature, 28.
Visher, Stephen S., 139.
Vogel, Howard H., 157.

Wabash College, Bacteriology at, 61.
War-time immunization, 28.
Weiss, Lucile J., 53.
Welch, Winona H., 96.
Welcher, Frank J., 134.
Wetzel, Marion, 144.
Whelan, Kenneth, 134.
Winter Meeting, 1943, Program, vii.

Xiphidiocercaria of virgula group, 156.

Yuncker, T. G., 57, 100.

Zangerl, Rainer, 158.
Zoology abstracts, 153.
Zoology, Section on, 153.

PROCEEDINGS

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R. C. CORLEY, Editor

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Sixtieth Annual Meeting
BUTLER UNIVERSITY
November 9, 10 and 11, 1944

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TABLE OF CONTENTS

Officers and Committees for 1944 . . . v
Program of the Winter Meeting . . . vii
Minutes of the Executive Committee . . . viii
Minutes of the General Session . . . xiii
New Members . . . xv
Necrology . . . 1
Presidential Address—Clyde A. Malott . . . 8

Anthropology

W. R. ADAMS and W. B. ADAMS: An Archeological Survey of Monroe County . . . 25
J. C. HOUSEHOLDFR: The Oliver Farm Site . . . 29
ELI LILLY: Tentative Speculations on the Chronology of the Walam Olum and the Migration Route of the Lenape . . . 33
GEORGE NEUMANN: Migrations and Origin of the Woodland Culture 41
PAUL WEER: Brantz Mayer and the Walam Olum Manuscript . . . 44
HELEN MARSH ZEINER: Botanical Survey of the Angel Mounds Site 49

Bacteriology

Abstracts of papers not published in full . . . 51
LYLE A. WEED: The Pathogenesis, Diagnosis, and Treatment of *Clostridium Welchii* Infection . . . 54
H. M. POWELL: On the Preparation of Purified Influenza Virus Vaccine . . . 66
D. B. PRATT: Morphological Characteristics of a Purified Thermophilic Cellulose Decomposing Culture . . . 75

Botany

Abstracts of papers not published in full . . . 79
C. L. PORTER: The Utilization of Staled Media by Fungi . . . 81
JONATHAN W. WRIGHT: Epidermal Characters in Fraxinus . . . 84
Indiana Plant Distribution Records, V. 1944 . . . 91

Chemistry

Abstract of paper not published in full . . . 100
JOHN H. BILLMAN and FRANK H. TRAVIS: The Reaction of Polyanhydrides with Thiophene . . . 101
E. ST. CLAIR GANTZ: A Rapid Method for the Qualitative Detection of Lead in the Presence of Bismuth, Copper and Cadmium . . . 105
C. E. KASLOW and R. DALE STAYNER: Oxides of Nitrogen in Ozonized Air . . . 107
F. C. MATHERS: Inhibited Acids for Recovering Tin from Tin Cans 112
DAVID RANKIN and ED. F. DEGERING: The Preparation and Properties of Certain Ether Derivatives of Starch . . . 114

P. D. SOMERS, JR.: Quantitative Determination of Non-Aminoid Nitrogen in Aliphatic and Aromatic Compounds 117
ELIJAH SWIFT, JR. and HELEN PHILLIPS HOCHANADEL: The Vapor Pressure of Dimethylamine from 0 to 40° C. 121

Geology and Geography

Abstracts of papers not published in full 124
G. DAVID KOCH: Variations in the Growing Season—Vigo County, Indiana 126
S. M. MCCLURE: High School Geography and College Grades in the Subject 130
STEPHEN S. VISHER: Indiana Floods 134
ALFRED H. MEYER: Toponomy in Sequent Occupance Geography, Calumet Region, Indiana-Illinois 142

History of Science

Abstracts of papers not published in full 160
B. ELWOOD MONTGOMERY: A Century of Odonatology in Indiana . 161
PAUL WEATHERWAX: Early Contacts of European Science with the Indian Corn Plant 169
JOHN S. WRIGHT: Men of Science in Indiana Past and Present ... 179

Mathematics

Abstracts of papers not published in full 184
SISTER GERTRUDE MARIE O. S. F.: The Great Mathematics Books in the College Curriculum 185

Physics

Abstract of paper not published in full 193

Psychology

Abstracts of papers not published in full 194

Zoology

Abstracts of papers not published in full 197
JOHN W. BAECHLE: A Summary of Bird-banding Activities from April, 1941, to November, 1944 201
W. R. BRENEMAN: Response of Chicks to Pituitary Gonadotropins and Pregnant Mare Serum 207
WM. A. HIESTAND and D. E. STULLKEN: Pharmacological Action of Morphine on the Red Fox, *Vulpes fulva* 214
B. ELWOOD MONTGOMERY: The Distribution and Relative Seasonal Abundance of the Indiana Species of Corduliidae and sibellulidae (Odonata) 217
W. E. RICKER: A First List of Indiana Stoneflies (Plecoptera) 225

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Research Grant Committee: A. L. FOLEY, Indiana University (term expires 1946); E. G. MAHIN, University of Notre Dame (term expires 1947); JOHN S. WRIGHT, Indianapolis (term expires 1948); M. S. MARKLE, Earlham College (term expires 1944); H. E. ENDERS, Purdue University (term expires 1945); C. A. MALOTT, Indiana University (ex officio); WINONA H. WELCH, DePauw University (ex officio).

DIVISIONAL CHAIRMEN

Anthropology, GEORG K. NEUMANN, Indiana University.
Bacteriology, LYLE A. WEED, Indiana University Medical Center.
C. M. PALMER, Butler University, Vice-Chairman.
Botany, BENJAMIN H. SMITH, Indiana State Teachers College.
Chemistry, F. B. WADE, Shortridge High School, Indianapolis.
Geology and Geography, A. H. MEYER, Valparaiso University.
History of Science, C. O. LEE, Purdue University.
Mathematics, PAUL M. PEPPER, University of Notre Dame.
Physics, MASON E. HUFFORD, Indiana University.
Psychology, H. H. REMMERS, Purdue University.
Zoology, W. H. HEADLEE, Indiana University School of Medicine.

EXECUTIVE COMMITTEE

(Past Presidents, Officers, Divisional Chairmen, and Chairmen of Standing Committees)

R. B. Abbott, C. A. Behrens, H. L. Bruner, S. Burrage, W. A. Cogshall, R. C. Corley, E. R. Cumings, J. J. Davis, C. C. Deam, W. E. Edington, H. E. Enders, A. L. Foley, R. C. Friesner, W. G. Gingery, R. E. Girton, W. H. Headlee, M. E. Hufford, Theodor Just, C. O. Lee, Eli Lilly, E. G. Mahin, C. A. Malott, E. S. Martin, M. G. Mellon, A. H.

Meyer, B. E. Montgomery, W. P. Morgan, G. K. Neumann, C. M. Palmer, F. Payne, P. M. Pepper, J. E. Potzger, R. R. Ramsey, H. H. Remmers, W. E. Ricker, B. H. Smith, F. B. Wade, F. N. Wallace, Paul Weatherwax, L. A. Weed, Winona H. Welch, J. S. Wright, T. G. Yuncker.

BUDGET COMMITTEE

(President, Secretary, Treasurer, Editor, and Chairmen of Committee on Relation of Academy to State, Program Committee, and Library Committee)

R. C. Corley, W. G. Gingery, C. A. Malott, W. P. Morgan, J. E. Potzger, F. N. Wallace, Winona H. Welch.

STANDING COMMITTEES

(Appointed by the President, Chairman of each committee named first)

Auditing: E. S. Martin, Arsenal Technical H. S., Indianapolis; K. S. Means.

Biological Survey: W. E. Ricker, Indiana University; R. M. Kriebel, W. P. Allyn, H. O. Deay, H. H. Michaud, B. E. Montgomery, C. M. Palmer, Dorothy Parker, Winona H. Welch.

Invitations: R. C. Friesner, Butler U.; W. N. Kellogg, O. B. Christy, J. F. Mackell, E. F. Degering.

Junior Academy of Science: H. E. Enders, Purdue U.; W. P. Allyn, O. B. Christy, M. S. Markle, C. L. Porter, F. B. Wade, M. M. Williams, T. G. Yuncker.

Library: W. G. Gingery, Washington H. S., Indianapolis; Nellie M. Coats, R. C. Friesner.

Membership: R. E. Girton, Purdue U.; F. J. Allen, G. F. Hennion, W. E. Martin, J. E. Potzger, J. E. Switzer.

Nominations: H. E. Enders, R. C. Friesner, W. E. Edington.

Program: J. E. Potzger, Butler U.; K. S. Means, N. S. Pearson.

Publication of Proceedings: R. C. Corley, Purdue U.; P. D. Edwards, Paul Weatherwax.

Relation of Academy to State: F. N. Wallace, State Dept. of Conservation; E. Y. Guernsey, Eli Lilly, H. J. Reed, J. S. Wright.

Representative on Council of A.A.A.S.: H. E. Enders, Purdue U.

Resolutions: B. E. Montgomery, Purdue U.; O. B. Christy, G. D. Koch.

PROGRAM OF THE WINTER MEETING

BUTLER UNIVERSITY

November 9-11, 1944

THURSDAY, NOVEMBER 9

7:30 P. M.

Meeting of the Executive Committee

FRIDAY, NOVEMBER 10

9:30 A. M. General Session

Address of Welcome. President M. O. Ross, Butler University.

Response. President C. A. Malott.

Necrology. Will E. Edington, DePauw University.

Men of Science in Indiana Past and Present. John S. Wright, Eli Lilly Company, Indianapolis.

A Critique of Science, Carroll D. W. Hildebrand, DePauw University.

A Historian Views Science. Louis M. Sears, Purdue University.

EXHIBITS.

1. Miss Nellie Coats, An exhibit of the Academy of Science Library.
2. Bird portraits, Rev. John W. Baechle, St. Joseph's College.

11:45 A. M. and 2:30 P. M. Sectional Meetings

6:00 P. M. Annual Dinner

Business Session.

President's Address. Significant Features of the Indiana Karst. President Cloyde A. Malott, Indiana University.

SATURDAY, NOVEMBER 11

9:00 A. M.

Taxonomists Meeting

MINUTES OF THE EXECUTIVE COMMITTEE

INDIANAPOLIS, November 9, 1944

The Executive Committee of the 60th session of the Indiana Academy of Science was called to order by President Malott in the Lincoln Room, Hotel Lincoln, at 7:30 p. m. The reports of officers and committee representatives were presented and accepted as follows:

Academy Trustee. Report of John S. Wright, Frank B. Wade and W. P. Morgan, Trustees of the Foundation Fund, Indiana Academy of Science, for the year 1943-1944.

Balance from the previous year		$ 477.62
Total receipts		396.39
Bonds called		2,600.00
Total		$3,474.01
Expenditures		
Series "G" U. S. Treasury Bonds	$3,400.00	
Collection charges	.25	
		3,400.25
Cash balance at Union Trust Company		$ 73.76

Assets in the Fund as of October 28, 1944

Five $1,000.00 U. S. Savings Bonds Series "D"—Cost	$ 3,750.00
$6,400.00 U. S. Treasury Series "G" Bonds—Cost	6,400.00
One $100.00 Muncie Masonic Temple Association Muncie Bond—Par	100.00
Six shares Standard Oil of Indiana Common Stock—Par	150.00
Total at par or cost	$10,400.00

Treasurer. W. P. Morgan presented a tentative financial report for the period from January 1 to October 31, 1944. His final report, approved by the Auditing Committee at the end of the year, follows:

Receipts

Balance on hand January 1, 1944	$1,413.46	
Dues and initiation fees	911.00	
A.A.A.S. refund for research grants	175.00	
Designated gifts	300.00	
Author's reprints Vol. No. 51	6.38	
Author's reprints Vol. No. 52	360.90	
Author's reprints Vol. No. 53	106.86	
Publications sold by librarian	16.00	
Refund from safety box rental	3.00	
		$3,292.60

Disbursements

1—Program Committee	$ 101.77		
2—Editor	200.00		
3—Expenses of Secretary	45.38		
4—Expenses of Treasurer	92.00		
5—Mailing Proceedings	36.72		
6—Stationery	91.67		
7—Lena Willkie—work in preparation of 50-year index	30.25		
8—Surety Bond and Safety Box rental	31.00		
9—*Research grant Dr. A. L. Foley	75.00		
10—Cost of reprints Vol. No. 52	369.27		
11—Cost of reprints Vol. No. 53	307.38		
12—Purchase of books for library	7.16		
13—Research grant Dr. J. A. Potzger	50.00		
14—Research grant Dr. W. E. Martin	37.50		
15—Refund to officers F. B. Wade	2.96		
		$1,478.06	
† Balance on hand		1,814.54	
			$3,292.60

* Granted in 1943 but check had not cleared when 1943 accounts were prepared for audit.

† Balance includes $569.25 in gifts, $69.75 is designated for use in completing work on 50-year index and $500 is to be used in the preparation of "Indiana Men of Science."

(Signed) W. P. MORGAN, *Treasurer.*
(Signed) ERSIE S. MARTIN
(Signed) KARL S. MEANS } *Auditors.*

Auditing Committee. E. S. Martin reports the accounts of the Academy Trustees and the Treasurer to be in perfect condition.

Bonding Committee. H. L. Bruner reported that the cost of bonding, $25.00, had been paid to the Hartford Accident and Indemnity Company, Indianapolis, Indiana.

The resignations of H. L. Bruner and W. A. Cogshall were accepted with regret. The Secretary was instructed to send notes of appreciation to these members who have served on this committee over a period of many years.

Editor and Publication of Proceedings. R. C. Corley reported that 9700 reprints had been mailed to the authors, 1600 copies of the Proceedings had been printed, 1000 of which would be cloth bound, and that the volume is composed of 223 pages, at a cost of $1305.13.

Research Grant. A. L. Foley reported that the committee had made a grant of $75.00 to Walter E. Martin, Department of Zoology, DePauw University.

Biological Survey. W. E. Ricker presented a history and summary of the work of this committee to date, copies of which are in the files of the Secretary. The activities of the committee, although retarded due to war conditions, are being continued.

Fifty-Year Index. Due to the death of George Hume Smith who had been preparing the Index, Ray C. Friesner, chairman of the committee, has continued the work and presented a progress report.

Library Committee. Nellie M. Coats, Academy Librarian, gave a splendid report of the accomplishments of this committee since the Academy Library was placed in the care of the Indiana State Library in 1898. The Academy Library consists of 3756 volumes. This fiscal year 191 volumes were bound at a cost of $207.13. The library's serial holdings are listed in the *Union List of Serials in Indiana Libraries* and in the Gregory *Union List of Serials*, second edition. Miss Coats requested that members return extra Proceedings for use in library exchanges. The Academy members enjoyed the library exhibit prepared by Miss Coats. J. S. Wright expressed on behalf of the Academy our deep appreciation of Miss Coats' interest in and splendid care of the Indiana Academy of Science Library.

Press Secretary. C. M. Palmer released for publication to approximately 275 newspapers of Indiana a 500-word article concerning the 1944 Academy sessions, through the Publicity Office of Butler University. The file of photographs of Academy Officers is in the Indiana State Library. Members are urged to send other photographs and papers of historic interest which are worthy of preservation in the library file. Important letters written by Indiana's early scientists should be saved for future reference.

Membership. R. E. Girton presented a tentative report.

Junior Academy of Science. H. E. Enders reported one additional club, the T-Square Club of Gary, Indiana, making a total of 52 clubs. The gasoline curtailment has made it impossible to hold the annual meeting in conjunction with the Indiana Academy of Science this year. The High School Science Clubs of the Indianapolis area held a joint meeting in connection with the Academy.

Relation of Academy to State. F. N. Wallace reported that the committee had requested an increase of the state appropriation from $1500.00 to $2000.00 per year to care for the increase in cost of publication of the Proceedings.

Relation of Academy to A.A.A.S. H. E. Enders, Academy Representative, was unable to attend the meeting of the twenty affiliated State and other Academies in Cleveland, Ohio, September 11, 1944.

Nominations. H. E. Enders presented the following names for election as Fellows:—Francis Hole, Geology, Earlham College; Dorothy Parker, Botany, Notre Dame University; Walter E. Martin, Zoology, DePauw University; Raymond M. Cable, Parasitology, Purdue University, and K. K. Chen, Pharmacology, Eli Lilly Co.

Membership Emeritus. B. D. Myers, Professor of Anatomy, Indiana University, was elected to Membership Emeritus.

Invitations. President Malott announced further appointments to this committee:—R. C. Friesner, chair., W. N. Kellogg, O. B. Christy, J. F. Mackell, and E. F. Degering.

Old Business. W. E. Edington, chairman of committee, presented plans for the History of Science in Indiana, including biographies of Indiana scientists. Executive Committee recommended that his plans be carried out.

T. G. Yuncker, chairman of committee, P. D. Edwards, and L. S. McClung presented the procedure for affiliation of Indiana associations or societies of biological, mathematical, and physical sciences with the Academy.

It is recommended that the Indiana Academy of Science invite all associations or societies of the biological, mathematical and physical sciences now organized and holding meetings in Indiana to become affiliated with the Academy of Science if such relationship does not already exist.

Affiliation is to imply that such organizations shall hold one of their meetings at the same time and place as the annual fall meeting of the Academy.

Members of the affiliated group should be invited to become members of the Academy though such membership would not be required. Such affiliated non-Academy members would participate in all of the privileges and activities of the Academy at the annual meeting with the exception of voting or holding office.

Non-Academy members would have the privilege of presenting papers before their section of the Academy according to the regulations of the Academy and section.

Publication in the Proceedings of the Academy would not be open to those who were not members of the Academy. Abstracts of such papers may, however, be published if approved by the editorial board of the Academy.

Representation in the Academy would be through a representative of their section who must be a member of the Academy. This representative would be a member of the Executive Committee.

The Chairman of the Program Committee or the President of the affiliating organization should work with the chairman of the related Academy section in the development of the joint program if this is desirable. If separate programs are to be scheduled, the chairman of the Academy section most nearly related to the affiliating organization should be informed of the program of the affiliating organization.

It is believed that all sciences which might become thus affiliated are already represented by a section in the Academy. The establishment of any new section is to be at the discretion of the Executive Committee.

These plans were adopted and the committee instructed to continue for a few years, extending invitations to said societies and making necessary arrangements for affiliation.

New Business. J. S. Wright was elected to succeed himself as Academy Trustee.

R. C. Friesner, chairman, and Scott McCoy were elected to committee on Bonding of Trustees.

T. G. Yuncker was elected to Research Grant Committee.

Adjournment, 10:00 p. m.

MINUTES OF THE GENERAL SESSION

BUTLER UNIVERSITY, November 10, 1944

President M. O. Ross, Butler University, delivered the Address of Welcome. President Malott responded in behalf of the Academy.

W. E. Edington presented the Necrology.

Minutes of the Executive Committee meeting of November 9, 1944, were read by the Secretary and approved by the Academy.

Following the annual dinner in the Travertine Room of Hotel Lincoln, R. E. Girton presented sixty-five applications for membership. The Secretary was instructed to cast an unanimous ballot for the sixty-five applicants.

H. E. Enders read the nominations of the committee as follows:—*President,* M. S. Markle, Earlham College; *Vice-President,* J. F. Mackell, Indiana State Teachers College, Terre Haute; *Secretary,* Winona H. Welch, DePauw University; *Treasurer,* W. P. Morgan, Indiana Central College; *Editor,* R. C. Corley, Purdue University; and *Press Secretary,* C. M. Palmer, Butler University.

The Divisional Chairmen elected in the sectional meetings for 1945 were announced as follows:—*Anthropology,* J. C. Householder, Indianapolis; *Bacteriology,* C. M. Palmer, Butler University; *Botany,* R. E. Girton, Purdue University; *Chemistry,* C. W. Holl, Manchester College; *Geology and Geography,* E. R. Smith, DePauw University; *History of Science,* John S. Wright, Indianapolis; *Mathematics,* Juna L. Beal, Butler University; *Physics,* R. E. Martin, Hanover College; *Psychology,* W. N. Kellogg, Indiana University, and *Zoology,* W. R. Breneman, Indiana University.

R. C. Friesner announced that the Committee on Invitations had selected Butler University for the 1945 Fall Meeting of the Academy.

A Tribute. W. E. Edington expressed congratulations in behalf of the Academy to the members who have been in the organization fifty years or longer:—John S. Wright, Arthur L. Foley, Henry L. Bruner, William Lowe Bryan, and two charter members, George W. Benton and Henry A. Huston.

Resolutions. B. E. Montgomery expressed on behalf of the Academy thanks and appreciation to the members of the Butler University staff and to the management of the Hotel Lincoln for their work in making this sixtieth session of the Academy pleasant and successful. A particular expression of appreciation was extended to J. E. Potzger and other members of the program committee, to R. C. Friesner, to President M. O. Ross of Butler University, and to Joseph Lautner, Director, and the members of the Jordan-Butler Philharmonic Choir. Thanks and appreciation were expressed to Louis M. Sears and C. D. W. Hildebrand for the excellent discussions which they brought to the Academy in the Morning General Session.

Vice-President R. B. Abbott introduced President Clyde A. Malott who delivered his Presidential Address on Significant Features of the Indiana Karst.

The 60th annual* meeting of the Indiana Academy of Science, with a general attendance of 201 and a dinner attendance of 130, was adjourned.

WINONA H. WELCH, *Secretary*

TAXONOMISTS MEETING

JOHN E. SEYBERT, Botanist, Eli Lilly Co., Chairman

The Plant Taxonomists held their meeting on Saturday morning at Butler University. J. E. Potzger, Butler University, was elected 1945 chairman.

ENTOMOLOGISTS MEETING

RALPH MORRIS, Assistant State Entomologist, Chairman

No meeting was held because of commitments of many entomologists preventing their attendance.

* No spring meeting was held during 1944.

NEW MEMBERS 1944

Adams, Mr. Wm. Richard, 432 S. Walnut, Bloomington .... A
Azbell, Mr. William, 203 Bloomington St., Greencastle .... Ph
Benedict, Mr. Paul Francis, 593 Main Cross St., Vevay .... Pre-Med
Billman, Prof. John H., 717 S. Henderson St., Bloomington C
Bittles, Mr. James A., 408 E. Walnut St., Greencastle C
Bloodgood, Prof. Don E., 915 N. Salisbury St., W. Lafayette .... S. Eng.
Brankle, Mr. Gordon B., 2743 Guilford Ave., Indianapolis .... Bo Z
Briggs, Mr. John P., 1226 N. Illinois St., Indianapolis .... C Z
Buls, Mr. Erwin J., Valparaiso Univ., Valparaiso .... G
Côffman, Mrs. Lyla Maye C., 415 Victoria St., South Bend .... A
Detmer, Miss Wanda Lee, 408 Park Avenue, Aurora .... G Ph
DeVol, Prof. Charles E., Marion College, Marion .... Bo Ba
Doub, Miss Margaret, 3355 Carrollton Ave., Indianapolis .... Z
Erselcuk, Mr. Muzaffer M., 348 S. Grant, Bloomington .... G Econ
Fessenden, Prof. William P., 3724 S. Wigger St., Marion C
Freeman, Prof. W. Otis, Dept. Geology and Geog., I. U., Bloomington .. G
Gerking, Dr. Shelby Delos, 518 East Second St., Bloomington .... Z
Graham, Mr. Jack W., Longden Hall, Greencastle .... Ph
Grayson, Mr. Richard R., 1922 South Third Ave., Maywood, Illinois .. Med
Green, Mr. Clinton C., 516 East University St., Bloomington .... G M
Griffith, Prof. Wallace Clayton, 1009 S. College, Greencastle .... M
Hayes, Mr. John C., 312 Main, Crawfordsville C
Herman, Mr. David T., 728 E. 3rd St., Bloomington .... Ps
Hicks, Prof. R. Lowell, Franklin College, Franklin C
Hill, Mr. Harris Ernest, 728 E. Third, Bloomington .... Ps
Hill, Dr. R. T., 841 Sharidan Rd., Bloomington .... Z
Hodson, Miss Margaret E., Marion College, Marion .... B Z
Howland, Dr. Warren E., 610 S. 9th St., Lafayette .... C Eng
Kaslow, Dr. Christian E., 414 Ballantine Rd., Bloomington C
Kimball, Dr. Grace C., 2105 E. Walnut St., Evansville, 14. .... Ba
Kleckner, Dr. Albert L., Pitman-Moore Co., 1200 Madison, Indianapolis .... Bo Z
Koontz, Prof. Dale F., 633 Anderson St., Greencastle .... Ph
Lash, Mr. Robert F., 1412 N. Walnut, Danville, Ill. .... Pre Med
Leskon, Miss Olive, Tolleston School, 1700 Taney, Gary .... M
Lundin, Mr. Robert W., 720 E. 3rd St., Bloomington .... Ps
Mansell, Mr. Othel Phillips, 604 Anderson St., Greencastle .... Ph
McKissick, Mr. Wendell B., Allison Eng. Corp., Maywood, Plant No. 5 .... Bio Chem
Milner, Mrs. Elizabeth, 1150 N. Meridian St., Indianapolis .... A
Morgan, Mrs. Ethel M. Chapin, 707 S. Locust St., Greencastle .... Ph
Morris, Mrs. Mabel S., Indianapolis Water Co., Indianapolis .... Bo Ba
Murray, Mr. F. Joseph, 1022 First St., W. Lafayette .... Ba
Newman, Mr. Samuel J., 375 West End Ave., New York 24, New York .... Pre-Med

Niccum, Mr. Warren L., 1121 South Eighth St., Goshen.........Pre-Med
Overman, Mr. Paul W., 720 Atwater Avenue, Bloomington. ....M
Powell, Mr. Clarence E., Eli Lilly Co., 740 S. Ala. St., Indianapolis.....Bo
Pratt, Mr. Darrell Bradford, 322 South Grant Street, W. Lafayette....Ba
Price, Prof. Dennis H., 2900 College Ave., Terre Haute..............Ps
Rediger, Prof. Milo A., Taylor Univ., Upland, Ind....................Ps
Robinson, Prof. Sid, 315 Mitchell Drive, Bloomington................Z
Roller, Prof. Duane, Physics Dept., Wabash College, Crawfordsville...Ph
Schmock, Rev. Norman G., St. Joseph's College, Collegeville..........G
Shirley, Dr. Mary Margaret, Psychology Dept., Ind. U., Bloomington..Ps
Sloan, Mr. Donald Eugene, 37 S. Harris Street, Indianapolis 8. ... .Bo
Smitha, Miss Doris, 543 Exetar Avenue, Indianapolis................Z C
Somers, Mr. Perrie D. Jr., 107 E. Fowler Ave., W. Lafayette... Bio Chem
Springer, Dr. Martha E., 410 East 3rd, Bloomington............... Bo
Strong, Prof. Martha T., 908 East Third St., Bloomington............Z
Swanson, Miss Jessie E., Valparaiso Univ., Valparaiso..............M
Swift, Dr. Elijah, Jr., 1220 Maxwell Lane, Bloomington.......... C
Tinkle, Dr. William J., South First St., Upland.. .... Bo Z
T-Square Club, Tolleston School, 1700 Taney, Gary.. ....M
Turrell, Mr. Eugene S., 605 S. Fess Ave. No. 3, Bloomington..........Z
Wagner, Mr. Kenneth A., Longden Hall, Greencastle................Bo
Wakim, Dr. K. G., 1014 East 1st St., Bloomington....................Z
Wolverton, Mr. George McComas, 3902 Caroline St., Indianapolis 5
.... Pre-Med

NECROLOGY

WILL E. EDINGTON, DePauw University

ARTHUR THOMPSON EVANS

Wellington, Illinois — Oxford, Ohio
May 22, 1888 — October 5, 1943

Arthur Thompson Evans, for fifteen years Professor and Head of the Department of Botany at Miami University, possessed that faculty of attracting to him students of unusual ability and imparting to them his own enthusiasm in the study of botany so that many of them continued their studies in graduate school and have since made enviable records in their chosen field. For many years he conducted tours by bus for students interested in botany where they camped out and studied nature first hand. One of these trips was made to Alaska. Obviously his untimely death at the age of fifty-five is to be deplored as a distinct loss to science.

He was born at Wellington, Illinois, and after completing his public school education he entered the University of Illinois from which he graduated in 1912. During the next two years he was principal of a high school in Michigan. In 1914 he went to the University of Colorado as an instructor in botany and he remained there three years during which time he secured the M.S. degree in 1915. He accepted a fellowship in botany at the University of Chicago in 1917 and the doctorate was conferred upon him the following year. The next year he spent as an assistant plant pathologist in the Bureau of Plant Industry, United States Department of Agriculture, being in charge of the cereal disease investigations in the Great Plains Region in 1918, and of the corn investigations in 1919. He then accepted the position of Professor of Biology and Dean in Huron College, but resigned the following year to go to South Dakota State College as Associate Professor of Agronomy and Associate in the Experiment Station. Three years later he was made Professor of Botany and Plant Pathology and Head of the Department of Botany. In 1928 he was elected Professor and Head of the Department of Botany at Miami University where he remained until his death on October 5, 1943.

Dr. Evans was the author of a number of research papers and college bulletins in morphology, cytology and ecology. He was joint author with R. J. Pool, of a *Laboratory Manual for First Course in Botany.* He was a Fellow of the American Association for the Advancement of Science, and he held membership in the Botanical Society and the Ohio Academy of Science, being vice-president of the latter in 1930. He was also a member of Sigma Xi and was listed in *Who's Who in America.* He appeared on the general program of the Indiana Academy of Science

in 1941 where he presented a paper on "Some Thoughts on Origin and Evolution," characterized by very interesting and original thinking.

A man of wide interests and intense enthusiasm who sought and secured results in whatever he undertook, he has left an indelible impress on the many students who came under his influence and are now making science their life work.

FRANK VERN GRAHAM

Miami County, Indiana	Muncie, Indiana
October 18, 1887	May 19, 1944

The community of Ball State Teachers College was shocked and saddened by the sudden and unexpected passing of Professor Frank Vern Graham on the morning of May 19, 1944. Professor Graham had not been well for some time but he had met his classes as usual the day before his death.

Professor Graham was born on a farm in Miami County on October 18, 1887. He received his elementary education in the Galveston schools and graduated from that high school in 1905. He attended Marion Normal Institute and later Indiana University from which he received the A.B. degree in 1916 and the Master's degree in 1920. He also spent the summers of 1937 and 1938 in graduate study at the University of Colorado.

Following his graduation from high school he taught two years in township schools of Cass County and two years in the Galveston grade schools after which he became Principal of a township high school in Benton County where he remained two years. From 1911 to 1915 he was Head of the Science Department of Hartford City High School. After graduating from Indiana University he taught in the Marquette, Michigan, High School and the McKeesport, Pennsylvania, High School, and in 1920 came to Ball State Teachers College as Profesor of Chemistry. While in McKeesport he worked during the summers in the research laboratories of the United States Steel Corporation in Pittsburgh.

Professor Graham was a good chemist primarily interested in the teaching of chemistry, in which he was unusually able and successful. He was interested in youth and their welfare, whether in college or in the public schools, serving as a troop committeeman in Boy Scout work, and at the time of his death he was a member of the college athletic committee. An active member and secretary of the church board of a Methodist Church in Muncie, he taught a Sunday School class and was a member of the Wesley Foundation.

He held membership in Alpha Chi Sigma, honorary chemistry fraternity, and Phi Delta Kappa, national education fraternity. Professor Graham joined the Indiana Academy of Science in 1920 and was a regular attendant at its meetings.

An earnest, able and sincere teacher, he had during his twenty-four years of service at Ball State Teachers College trained a number of students in chemistry who have gone on to successful careers in that field. It is indeed to be regretted that he passed on at the comparatively early age of fifty-six.

RICHARD LIEBER

St. Johann-Saarbruecken, Germany — McCormick's Creek State Park
September 6, 1869 — April 15, 1944

Many of the Founders of the Indiana Academy of Science were naturalists rather than specialists in narrow fields and the Minutes of the early years of the Academy have numerous resolutions and suggestions looking toward the conservation and preservation of Indiana fauna, flora and other resources. The names of Amos W. Butler, Stanley Coulter, Carl H. Eigenmann, Robert W. McBride and Willis A. Blatchley come to mind as men who were true Hoosier naturalists and who wrote and worked for conservation. But it remained for a young immigrant to direct the movement that brought about that phase of the conservation program which resulted in Indiana's State Park system. This immigrant was Richard Lieber.

Richard Lieber was born in western Germany where his ancestors were land owners and foresters. He received his education in the Municipal Lyceum and the Royal Lyceum in Dusseldorf, Germany. He came to the United States in 1891, while on a world tour, and went to Indianapolis to visit an uncle who came to America after the revolution in Germany in 1848. However, he decided to stay and first took employment in a hardware store. Being an accomplished pianist he later became music and art critic for the old *Indianapolis Journal* and the *Indiana Tribune* which position he held for eight years. He became a naturalized citizen in 1901. Leaving newspaper work he later became associated with an importing and jobbing firm, and continued this work until the conservation work required his full time.

In the first decade of this century President Theodore Roosevelt was active in conservation work and in 1908 he called a conference of governors of the states to discuss conservation. Indiana already had a State Board of Forestry at that time, Stanley Coulter being appointed a member of it in 1902. Mr. Lieber was deeply interested in conservation and became active in that work, and in 1912 he was chairman of the last meeting of the National Conservation Association which met in Indianapolis that year. Three years later he was made chairman of the Indiana State Park Commission. When the Indiana State Department of Conservation was created, he became its first director and retained this position until his resignation in 1933. Stanley Coulter was a member of the Conservation Commission during all these years so that the two men worked together in the development of the State Park system. During Mr. Lieber's tenure the Department of Conservation acquired control of three state forests, five fish hatcheries, three bird and game sanctuaries, two pheasantries, ten state parks, five historic and one natural monuments, with a total of 47,243 acres. In 1917 Governor Goodrich appointed him military secretary with the rank of colonel and made him secretary of the State Board of Forestry.

In 1921 Mr. Lieber became associated with Stephen T. Mather, Director of National Parks, in organizing the National Conference on State

Parks. Mr. Lieber served as chairman of the Conference from 1932 to 1939 and then became chairman of the Conference Board.

During all these years Mr. Lieber spoke and wrote for the furtherance of national and state conservation. He was a nature lover and sportsman and in his travels he visited forty-five of the States, Europe, Egypt, Canada and Mexico. He wrote one book, *America's Natural Wealth*, published in 1942, emphasizing the need for conservation.

He was the recipient of many honors. The Pugsley Gold Medal of the American Scenic and Historical Preservation Society was presented to him in 1933. Four years later the Chicago Regional Planning Commission presented him an illuminated scroll citing his contributions, and Wabash College conferred the Sc.D. degree upon him in 1938. A movement sponsored by twenty-one historic, educational, religious, civic and military organizations led to the unveiling in 1932 of a bronze bust of Mr. Lieber in the Turkey Run State Park.

Dr. Lieber was a consultant member of the advisory board of the United States national park service. He was a vice-president and director of the American Planning and Civic Association. He held memberships in the American Forestry Association, the national Audubon Society, the Indiana Nature Study Club, and others. He was listed in *Who's Who in America*. He became a member of the Indiana Academy of Science in 1919, and later was elected a Fellow and its vice-president in 1932.

A week preceding his death he had gone to McCormick's Creek Canyon State Park with Mrs. Lieber for a rest, and he passed away unexpectedly after a heart attack. His ashes were placed at his request in the Turkey Run State Park.

Richard Lieber was one of Indiana's staunchest citizens, and he left behind him a monument of civic and national service. His labors have brought and will continue to bring joy and happiness to millions who will be brought closer to nature and the realization of the importance of conservation and preservation of our state and national resources.

ARTHUR RENWICK MIDDLETON

Webster, New York	West Lafayette, Indiana
May 8, 1869	February 4, 1944

College and university faculties today are composed largely of specialists with very few scholars. The rapid development of the sciences and the tremendous amount of reading and study required to keep abreast has narrowed the specialization even to subdivisions of any given field of science. Hence it is rare that one finds an excellent scientist and a real scholar in one and the same individual. But such a man was Arthur Renwick Middleton, one of Purdue's grand old men, who retired in 1939 after thirty-three years of service, and passed away on February 4, 1944.

Dr. Middleton received his early education in the Webster Union school and then graduated in 1891 from the University of Rochester with the A.B. degree. Up to this time he had studied Latin, Greek, French,

German, mathematics, rhetoric, physics, geology, astronomy, psychology, ethics, history and political economy, and one three months course in chemistry. Following his graduation he taught for two years in the Collegiate Institute at Marion, New York, and for three years each in DeVaux College at Niagara Falls, and the Mellen School in Buffalo. During this time he had also been studying law, but finding that not to his liking, he decided to take up the study of chemistry. Accordingly he entered the Graduate School of Cornell University in 1899 and five years later received the Ph.D. degree. He then taught a year each in McGill University and the Central High School of Saint Louis before coming to Purdue University in 1906 as Assistant Professor of Chemistry. He was promoted to Associate Professor of Inorganic Chemistry in 1912, and to a full professorship in 1917. He served as acting head of the Department of Chemistry in 1925-1926 and again in 1930, and was Chairman of the Department from 1931 to 1936, retiring voluntarily from the chairmanship in order to devote his time to the preparation and publishing of a textbook.

In 1907 he volunteered as an abstractor for *Chemical Abstracts*, and in 1923 he was made an assistant editor and for the next fifteen years practically everything published throughout the world in inorganic chemistry passed through his hands. His training in the leading scientific languages enabled him to do this work successfully. With the reorganization and expansion of the Graduate School at Purdue in 1924 chemistry became one of the first fields in which work leading to the Ph.D. degree was offered, and with it came the foreign language requirements. Many graduate students were deficient in these languages and for years Dr. Middleton spent many evenings helping these students to acquire that proficiency in the essential languages necessary to carry on their research reading.

Besides being an active member of the American Chemical Society, Dr. Middleton was a member of the International Committee on Nomenclature in Inorganic Chemistry. He was a member of Phi Beta Kappa, Sigma Xi and Phi Lambda Upsilon. He joined the Indiana Academy of Science in 1906, was made a Fellow in 1918, and served on the Editorial Committee of the *Proceedings* for several years. He was author of a number of research papers and joint author with John W. Willard of a textbook *Semimicro Qualitative Analysis* published in 1939.

Dr. Middleton was an authority in his chosen field and he insisted on thoroughness in his students. It was a pleasure to listen to him conduct a doctorate examination, for his wide knowledge of his subject enabled him through his questions to suggest to the candidate topics for further study and research. He had little patience with superficial scholarship and he did much to bring the Department of Chemistry at Purdue to the high standard which it has attained. He pursued numerous hobbies with that same zeal and enthusiasm that characterized his scientific work. It has been well said of him that he was "A man high in the ranks of his profession, wide in his intellectual interest, an honest man, firm in his convictions and sturdy in his defense of them, loyal to his friends, conscientious and thorough in the performance of his duties, his serious-

ness tempered by a hearty sense of humor, his knowledge and personality firmly fixed in the lives of more than a generation of Purdue students and faculty."

LOUIS JOHN RETTGER

Huntingburg, Indiana
October 19, 1867

Bedford Village, New York
December 1, 1943

One of three brothers, all distinguished in American science, and brother of the wife of a past president of the Indiana Academy of Science, Louis John Rettger was distinctly an Indiana product. Born at Huntingburg, he attended the public schools there and then entered the Indiana State Normal School, now Indiana State Teachers College, from which he graduated in 1886. He spent the next three years at Johns Hopkins University, receiving the A.B. degree in 1888 and continuing another year as a graduate student and assistant in biology. He became an instructor in Indiana University in 1889 and received the Master's degree the next year. Following one year of teaching science in South Bend High School he returned to the Indiana State Normal School in 1891 as Professor of Physiology, where he remained until his retirement in 1938 as Emeritus Professor. During this period he spent one year, 1895-1896, in graduate study at the Universities of Heidelberg and Berlin, and later, in 1909, he received the Ph. D. degree from Johns Hopkins University. Following the reorganization in 1915 that changed the Normal School to Indiana State Teachers College, Dr. Rettger became Head of the Department of Physiology. In 1923 he was made Dean of Science, and in 1931 Vice-President of the College. After his retirement he had planned to travel but the war prevented this and he then made his home with his daughter in New York.

Dr. Rettger was the author of two textbooks, *Studies in Advanced Physiology*, 1898, and *Elements of Physiology and Sanitation*, 1916. He also wrote several research papers on the coagulation of the blood and a number of articles on physiology and educational topics. Several of these were published in the *Proceedings of the Academy of Science.*

He became a member of the Indiana Academy of Science in 1893 and was made a Fellow in 1896. He was Editor of the *Proceedings* for 1911 and 1912. He was elected vice-president of the Academy in 1926 and president in 1929. Dr. Rettger was also a Fellow in the American Association for the Advancement of Science and he held membership in the National Educational Association. He was an associate member of the Terre Haute Academy of Medicine.

An earnest and inspiring teacher and a spirited and forceful lecturer, Dr. Rettger was widely known to teachers throughout Indiana, a very large number of whom had been in his classes. He had lectured one or more times at teachers' institutes in nearly every county in the State. A man of strong personality, but gracious and charming, he wielded great influence over students and faculty at Indiana State Teachers College and he did much to give his college the excellent reputation it has attained

as a teachers training center. Dr. Rettger is one of that distinguished group of educators who have rendered such splendid service to the State of Indiana during the past half century.

GEORGE HUME SMITH

Indianapolis, Indiana — Indianapolis, Indiana
March 1, 1896 — February 7, 1944

George Hume Smith had just about completed his work on the fifty-year cumulative index of the *Proceedings of the Indiana Academy of Science* when he was stricken with a serious illness that brought his life to a close at the comparatively early age of forty-seven. He apparently realized the seriousness of his illness for he requested his mother to send the *Index* to Dr. Friesner at Butler University and also to deliver his teaching records to that University and to mail certain biological abstracts which he had completed. This recognition of duty and conscientiousness in its performance was characteristic of the man, and his end was probably hastened by his insistence on meeting his Army classes when he was really physically unable to do so.

Born in Indianapolis, he received his public school education there and graduated from Shortridge High School. He intended studying the classical languages but after taking a course in botany he became intensely interested in the plant sciences. He entered Wabash College and upon his graduation in 1918 immediately went to Cornell University as a graduate student and assistant plant pathologist. He received the A.M. degree from Cornell in 1919 and the Ph.D. four years later. He spent the next four years as an instructor in botany at the University of Illinois. In 1927 he joined the editorial staff of *Biological Abstracts* and devoted his full time to this work for the next two years. He continued to do some of this abstracting up to the time of his death. He served as acting Assistant Professor of Botany at the University of Missouri for one year and then became Seessel Research Fellow at Yale University for a year. He was field assistant in the Elm Disease Survey in 1934. Following a year as a professor of biology and chemistry in the Passaic, New Jersey, Junior College, he became an assistant botanist in the division of cotton and fiber crops, Bureau of Plant Industry, United States Department of Agriculture, for a period of time. Returning to Indianapolis he began teaching mathematics to Army classes at Butler University and was engaged in this work at the time of his death.

Dr. Smith was a member of the Botanical Society and the Phytopathological Society and a Fellow in the American Association for the Advancement of Science. He joined the Indiana Academy of Science in 1940 and was active in its work. He had written and published several research papers in botany.

A thorough, conscientious, painstaking worker, he was deeply interested in the success of his students and gave freely of his time to help them in their work. During his association with the Academy he had assumed the responsibility of making a complete *Index* of the first fifty volumes of the *Proceedings*, and he had almost completed this work when he was stricken. His passing is a real loss to science and to the Academy.

PRESIDENTIAL ADDRESS

Significant Features of the Indiana Karst

CLYDE A. MALOTT, Indiana University

The pit-marked lands of southern Indiana, where placid streams disappear and riotous storm waters are swallowed up and disgorged from mysterious subterranean routes, constitute a singular geomorphic area of unusual lure and challenging inquiry. During the past 60 years the Indiana Academy of Science has held eleven field meetings in this area and at least 30 papers bearing on the region have appeared in the Academy Proceedings. It has been my pleasure to act as guide on a

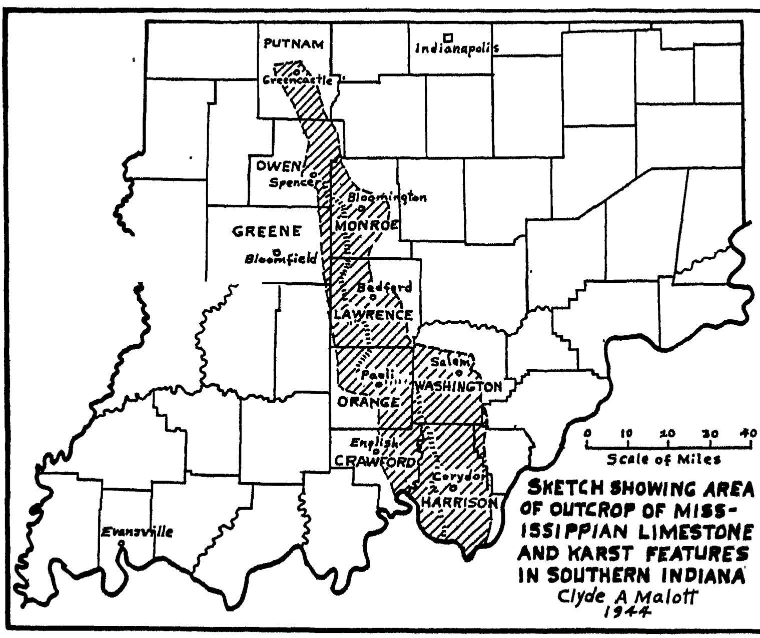


Fig. 1.

number of the Academy field excursions in this unusual Indiana region, which, also, has been the field of my own most interesting researches. I propose to identify and set forth the more significant characteristics of some 35 features peculiar to limestone terrains and well exemplified in the karst region of southern Indiana.

Subterranean drainage with an associated sinkhole topography characterizes a considerable portion of the outcrop belt of the Mississippian limestones of middle southern Indiana. The limestone belt, comprising

an area of approximately 2,000 square miles, is an irregular strip of upland of varying width extending south-southeasterly from near Greencastle to the Ohio River. It is a northern extension of a greater area in western Kentucky. It composes the Mitchell plain and the eastern margin of the Crawford upland, two distinct topographic units separated by a much dissected and indented scarp in southern Indiana. (Fig. 1.)

Limestone is an essential underlying bedrock requirement of the underground drainage and the well developed karst topography of the area. The limestone formations are the Harrodsburg (Warsaw), Salem, St. Louis, Ste. Genevieve, and one or more of the Chester limestones at the top. There is much thinning of the limestones on the north in Putman and Owen counties, where the country also becomes partially or wholly covered with glacial drift. Southward the total thickness of the limestones reach a maximum of approximately 575 feet. The limestone formations dip westerly at a rate of about 30 feet to the mile, and accordingly the Harrodsburg is the first to appear on the east and the first to pass below drainage. The other formations appear successively on the west and likewise pass below drainage. The underground drainage of this limestone belt with its innumerable sinkholes and its sinking streams is best developed on the St. Louis and Ste. Genevieve limestones through much of their outcrop area in Monroe, Lawrence, Orange, Washington, and Harrison counties.

While an area of some 2,000 square miles is composed of limestone, not all of it is characterized by underground drainage and karst topography. At least 500 square miles of the upland limestone area possess normal surface drainage. Some of this normal surface drainage area is high upland and is strangely without sinkholes. The upper drainage of Lost River occupies such an area in the very midst of the karst terrain. Sinkholes with little or no stream drainage dominate an aggregate of about 650 square miles, and they are occasionally present and somewhat characteristic of an additional area of about 450 square miles. Minor valleys with limestone floors, usually characterized by sinkholes, lose their drainage to underground routes in the eastern margin of the Crawford upland. These valleys have an aggregate area of about 400 square miles. Hence, karst features are characteristic of some 1,500 square miles of the limestone area.

Karst features, such as sinkholes, small sinking streams, and shallow caverns are present in other limestone areas in Indiana, but they do not dominate the topography. Perhaps as much as 150 square miles of the outcrop area of the Devonian limestone of Clark, Jefferson, and Jennings counties have scattered local areas of karst in which sinkhole drainage is well developed.

The term *karst* is used in the sense of the dominance of landscape features dependent upon subsurface solution and the diversion of surface waters to underground routes. Its most characteristic topographic feature is the sinkhole, though sinking streams, caverns, resurgences, and other features attending underground drainage in limestone areas compose the karst assembly. Many of the features of the karst assembly are not distinctly topographic, or they are only occasionally present in the karst

terrain. An enumeration of the many features characteristic of karst areas requires some special terms, but many of the features are characterized by descriptive terms or phrases more or less self-explanatory.

The surface and near-surface solution of limestone by descending percolating waters leaves a residue of surface red clay which mantles the limestone bedrock, masking from view the erose rock surface and filling the widened joints of the irregularly dissolved limestone. This residual red clay is the *terra rossa* which is so characteristic of limestone areas and karst terrains long subject to surface decomposition. Locally, where relief permits or where the *terra rossa* has been washed away, the exposed limestone is etched, pitted, grooved, or otherwise made rugged through differential solution. Such barren, etched and rugged surfaces are designated as *lapies*. Lapies surfaces are small and only occasionally present in the Indiana karst. A good example of such a surface is present along the west side of the Monon Railway a short distance south of White River in Lawrence County, where the surface soil was removed from the Salem limestone to construct the railway grade more than 80 years ago. An area of an acre or more here exhibits barren rock surfaces with characteristic lapies features and patchy terra rossa. In such surfaces and elsewhere in the near surface limestone, joints are occasionally opened and widened by solution into gaping fissures known as *grikes*.

The most common and distinctive feature of the karst terrain is the *sinkhole*. Topographically, it is a depression. It varies in size from a mere dent to expansive depressions of considerable depth. Perhaps the funnel-shaped depression is the ideal form. Sinkholes with gentle, soil-covered sides and flattish bottoms are the most common. This form, largely developed by solution under a soil mantle, may be designated by the European term *doline*. Steep-sided, rocky, and abruptly descending forms are frequently called *collapse sinkholes*, after the manner of their

Fig. 2. View of a collapse sinkhole, entrance to Nicols Cave, Lost River region four miles southwest of Orleans, Orange County.

development. (Fig. 2.) Some of the collapse sinkholes may resemble the abrupt and deep forms of the Yucatan region known as *cenotes*, which are developed probably as much by stopping from below as by collapse. Another form, only occasionally present, is the gaping, deep, well-like form or hole, which may be called *abime*, after the French term.

Some sinkhole depressions, probably originally produced by collapse over an underground stream, have become considerably modified. Occasionally they allow the unroofed portion of a cavern or an underground stream to show. Such specialized depressions may be called *karst windows*. They may have a stream flowing across the bottom either continually or intermittently. Some of the karst windows are entrances to caverns both upstream and downstream, such as the well-known Twin Caves at the Spring Mill State Park. The term may be applied to any specialized sinkhole form which shows evidence of stream or cavern unroofing, whether a mere peephole or one of considerable area. Some of the karst windows may have become greatly enlarged and possess alluviated floors in which waters rise and sink. These are the *uvala* forms of the West Indian karst. In the Lost River region of Orange County, such depressions with steep-sided perimeters and alluviated floors are called *gulfs*, such as the Wesley Chapel Gulf, five miles southwest of Orleans.

It is not uncommon for flat-bottomed sinkhole depressions to become clogged with inwashed clay, so that they hold the waters which drain into them, producing *sinkhole ponds* or karst lakes. (Fig. 3.) In localities

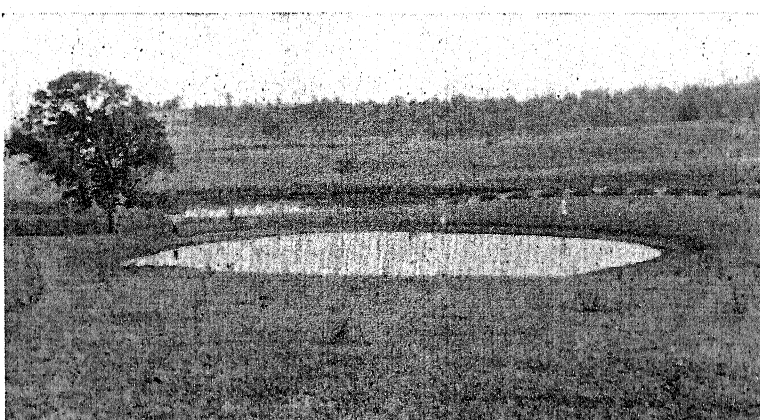
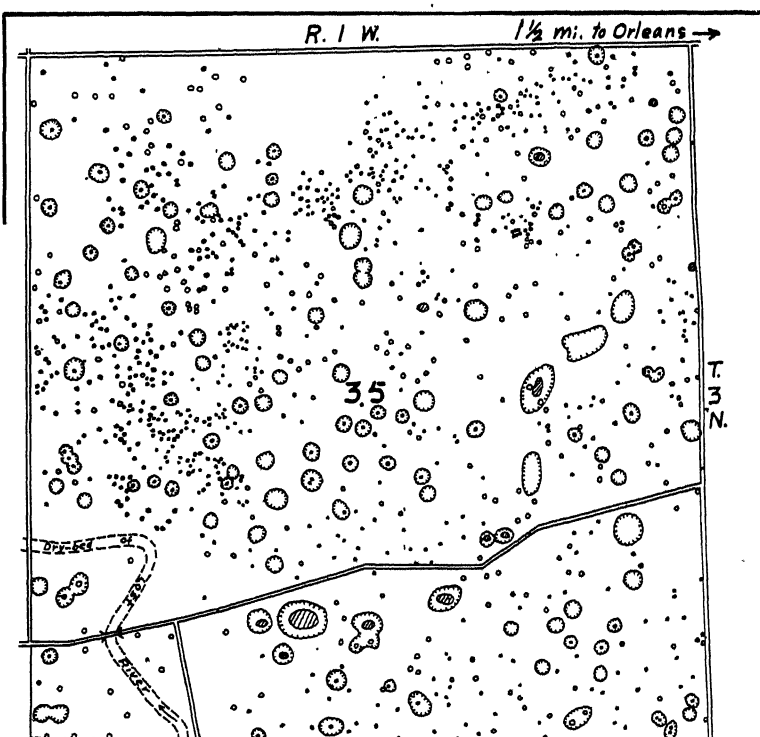


Fig. 3. View of a sinkhole pond in a doline, sinkhole plain four miles southwest of Bloomington, Monroe County.

of poor surface drainage shallow *solution pans* are occasionally developed, These shallow depressions are but slightly below the surrounding surface and may embrace a considerable expanse. One in the upper Lost River region in Washington County, two miles east of Livonia, contains more than 30 acres. Such solution pans frequently are swampy or contain some open water during wet periods, and these may be termed *karst swamps* or karst fens.

Sinkhole depressions are developed in great numbers in much of the upland limestone plain. They form the principal relief of extensive areas between the larger intrenched valleys. They use up nearly all of the upland surface area, and much of the limestone terrain becomes a veritable *sinkhole plain*. They vary in depth from a few feet to a maximum of upwards of 100 feet. The vast majority of them are more or less symmetrical depressions from 10 to 30 feet in depth, and embrace areas of a few square rods to an acre or more. Some of them possess obvious holes in the bottom where the rain-born waters reach into subterranean leads, while others have no visible places of water descent. The larger more expansive sinkhole depressions are frequently compound ones, containing merged depressions. Some of them contain smaller ones on their sides, as if the rain-born waters must descend below into the solution-riddled limestone grid rather than waste time in further surface flow. The sinkhole plain in large areas is a veritable regional sieve with



Dolines 100 ft. or more across and 10-30 ft. deep
Karst ponds
• Small sinkholes with visible holes
○ Small sinkholes without visible holes in bottoms

Plane table map of 1022 located sinkhole depressions in one square mile of the Lost River sinkhole plain southwest of Orleans, Orange Co., Indiana.

From field map by Malott and Shrock, 1929.

Fig. 4.

thousands of surface hoppers which convey the rainfall to underground routes. Large areas in Lawrence, Orange, Washington, and Harrison counties contain hundreds of sinkhole depressions to the square mile which furnish complete drainage to underground routes. An actual count from a plane table map made by the writer and Robert Shrock in 1929 in the Lost River sinkhole plain southwest of Orleans, Orange County, reveals 1,022 sinkholes in one square mile. (Fig. 4.) No surface stream can cross such an area, and Lost River and all its former tributaries are swallowed up in this expansive sinkhole plain. It is quite probable that as much as 400 square miles of the karst terrain contains an average of 500 individual sinkholes each, and it is not unlikely that the whole karst area of southern Indiana has a total number in excess of 300,000 sinkholes.

The sinkhole plain is so effective in absorbing the local rainfall that few streams are able to cross it as surface streams. The larger streams heading beyond it, such as Indian Creek, Blue River, and East White River, cross it in abrupt valleys intrenched 100 feet or more with few or no tributary valleys. The smaller streams and some of considerable size are *sinking streams* which lose their waters to underground routes. They terminate as surface streams. The *sink* of a stream simply denotes the disappearance of a stream at some place, such as the sink of Lost River, the sink of Stampers Creek, etc. The sink of a stream commonly takes place in obvious and occasionally large openings which are called *swallow-holes.* Many of the sinking streams have numerous channel swallow-holes into which their waters are discharged, while others lose their waters in a single terminal swallow-hole.

Sinking streams are expected features in karst areas, and they constitute an important geomorphic aspect of karst terrains. Beede (1911)

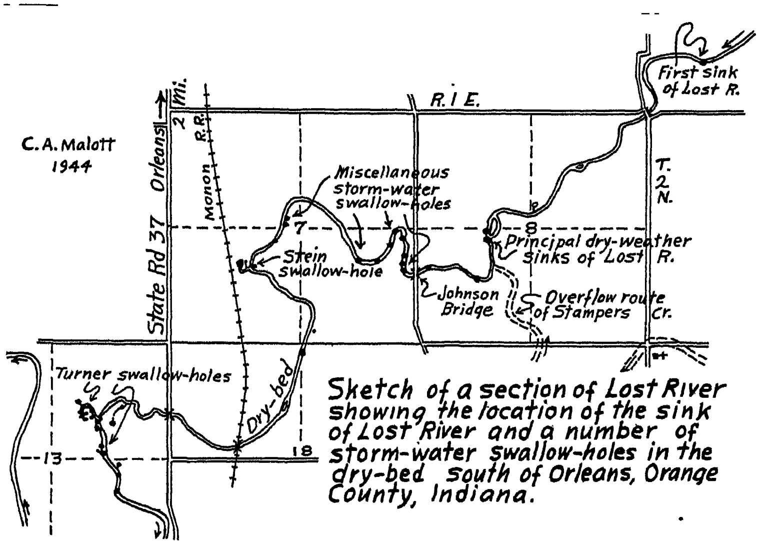


Fig. 5.

described the sinking and diversion of several streams on the upland limestone plain west of Bloomington, Monroe County, where some 15 square miles in area have become lost from the headwaters of Indian Creek and added to the more deeply intrenched valleys on either side. Elrod (1876 and 1899) and Malott (1922 and 1932) have clearly set forth the characteristics of the Lost River drainage of Orange County. Lost River, after gathering its waters from 53 square miles of non-karst limestone upland, sinks in a number of channel swallow-holes, except in times of very low water when the small flow is lost in a single pool without evidence of a swallow-hole. In times of heavy rainfall the swollen stream discharges across the sinkhole plain in a meandering storm-water channel more than 20 miles in length. Such a storm-water channel, normally dry, but kept open, is called a *dry-bed*. Along its dry-bed are many small swallow-holes and a few major ones reached only by muddy storm waters. (Figs. 5 and 6.) The larger ones are characterized by

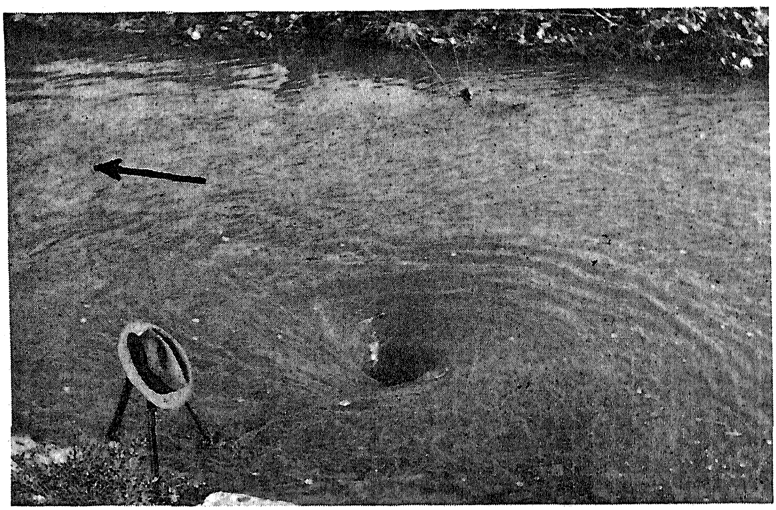


Fig. 6. View of a vortex in the storm waters in the dry-bed of Lost River. About five cubic feet per second are disappearing here in a small swallow-hole about one-half of a mile below the dry-weather sinks of Lost River. Sinking streams rarely disappear in vortices such as the one here pictured.

an accumulation of drift-wood which may be called *swallow-hole rafts*. Stampers Creek, formerly connected with Lost River as a tributary and now draining about 15 square miles, has only one main swallow-hole at the terminous of its surface channel. It does not maintain a dry-bed channel, though on rare occasions an excess of its accumulated storm waters overflow across the country to Lost River.

Some streams have continued to sink in a terminal swallow-hole for such a long time that they have cut their valleys much below the level of the plain or below their former surface courses. Such valleys terminate abruptly, and having no continuation, are known as *blind valleys*. A good

example of a blind valley occurs along State Road 37, near Needmore, Lawrence County, where a small stream enters a swallow-hole in a valley cut 60 feet lower than its former surface course. A small blind valley is present on the main campus of Indiana University at Bloomington, and they are present at numerous places where small streams sink in the sinkhole plain. Blind valleys become the sites of temporary lakes when storm waters accumulate about the terminal swallow-holes into which the waters feed more slowly. Stampers Creek valley of the Lost River region is a broad, shallow blind valley in which storm waters accumulate as much as 20 feet deep and spread widely over several hundred acres following continued heavy rains. It takes as long as 23 days for these accumulated waters to completely vacate the valley. Ponded storm waters in some of these broad, shallow blind valleys frequently become a flood menace, such as in the terminal blind valley of Sulphur Creek in the town of Orleans, Orange County.

In contrast to the litter-glutted swallow-holes of many sinking streams, a disappearing stream may flow boldly into a gaping cavern. Such an opening to an underground course may be called a *cave-inlet* instead of a swallow-hole. Cave-inlets are rare in the Indiana karst. Bridge Creek of the American Bottoms region of eastern Greene County enters its underground route through such an opening.

The absorption of surface waters into sinkholes and swallow-holes initiate or furnish waters to *underground streams* which course through conduits or cavernous routes of considerable lengths before being returned to the surface at lower levels in the limestone terrain. The routes of some of these underground streams are known and have been explored in part, such as certain sections of underground Lost River, the lower parts of underground Mosquito Creek in the Donaldson cavern system

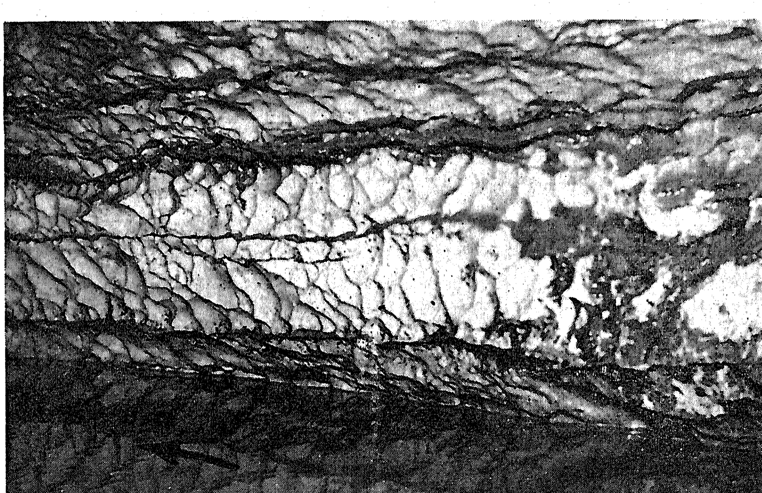


Fig. 7. View of an underground stream and storm-water sculpture in Salts Cavern, one-half of a mile south of Georgia, Lawrence County.

of Spring Mills State Park, and a considerable section of underground Sinking Creek, near Hardinsburg in Washington County. Where underground streams occupy caverns, they may be called *cavern streams.* (Fig. 7.) Untold numbers of underground and cavern streams are not open to exploration. They are sealed to the light of day and their routes are little known. Some of them are at shallow depths, but many of them pass more or less directly underneath high ridges and are deep beneath the surface at such places. The shallow ones frequently may come momentarily to the light of day in karst windows which indicate the courses of their routes here and there.

The return of the waters of the larger underground streams to the surface, either in the lower parts of the same valley or into another valley, produces springs of considerable size and of varying volume, which may in general be called *karst springs.* Many of these resurgences are known to be the reappearances of the waters of sinking streams, and are called *rises* in southern Indiana, such as the rise of Lost River, the rise of Stampers Creek, etc. Many of the rises are attended by moderate flows of clear waters during dry periods, but following heavy rains they send forth great volumes of turbid storm waters and are impressive features along the deep-set valleys of the western margin of the karst area. (Fig. 8.) The larger and more impressive ones are

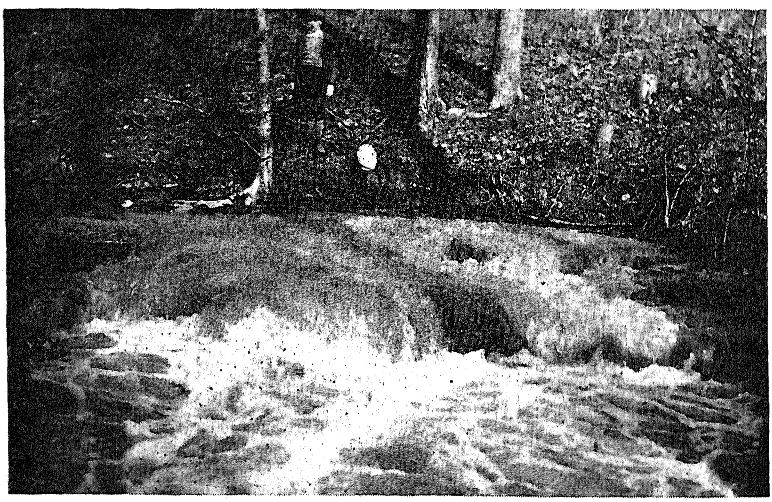


Fig. 8. View of one of the storm-water rises along Caplinger Branch three miles southeast of Paoli, Orange County. This is a storm-water rise only. The waters come from a small tubular cavern.

artesian in character and issue from *rise-pits* of considerable size and depth. (Fig. 9.) The great Harrison karst spring, some six miles west of Corydon in Harrison County, is 80 feet wide, 110 feet long, and at least 35 feet in depth. It is filled with clear waters during dry periods, but

following heavy rains it becomes greatly swollen with muddy storm waters which rise vigorously from the bottom of the great rise-pit. A view of the great volumes of storm waters issuing here at such times leaves the observer with little doubt concerning the presence of a large water-filled cavern ending in the great rise-pit below the local drainage level of Blue River valley at this place. The waters come from the higher sinkhole plain and the karst valley areas east and north of the great spring, which in reality is the terminus of a large underground drainage system arising here from its underground route under a forced artesian flow.

Rise-pits are not always water-filled. They may be the sites of *wet-weather rises*, used only during rainy periods, and are *dry rise-pits* during most of the time. Such a rise-pit occurs near the dry-bed of Lost River a short distance north of the well-known Pitcher Cavern, about four miles southwest of Orleans, Orange County. Dry rise-pits occasionally contain worn and polished pebbles which partially clog the

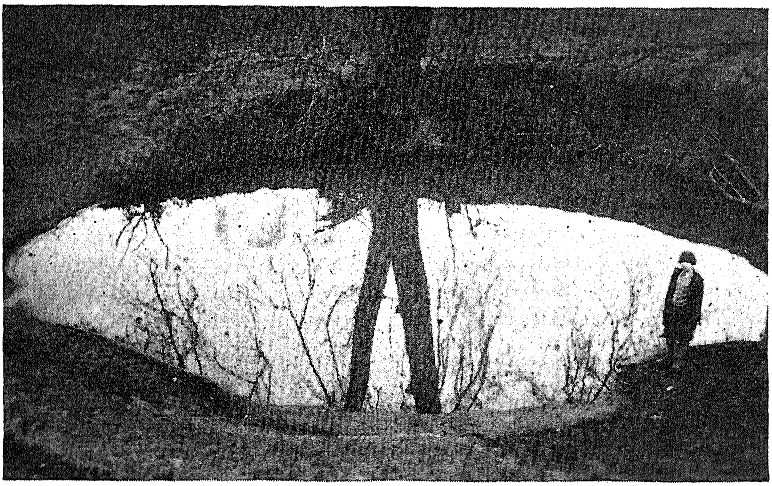


Fig. 9. View of the rise-pit of Lick Creek, locally known as Half Moon Spring, about three miles southeast of Paoli, Orange County.

openings through which the storm waters vigorously rise. They become veritable pebble grinding mills, intermittently active, and indicate the actions probably taking place in the deep rise-pits constantly filled with rising waters.

Not infrequently an underground stream will issue at the head of a valley. The waters may flow directly out of an open cavern which serves as a *cave-outlet* of the underground stream. The mouths of Donaldson and Hamer caverns of the Spring Mills State Park are excellent examples of such cavern outlets of underground streams. Such underground stream outlets are characteristic of the eastern margin of the karst area and are rare on the western margin. Underground streams commonly issue through broken rock or talus which wholly obscures the terminus of

the cavernous route from which they flow. Such issuing waters are mere resurgences or karst springs, and no special term is applied to them. Such resurgences in common with those issuing directly from caverns develop steep valley heads of a very striking character, which are under gradual retreat through the sapping action of the issuing waters at their bases. The term *steep-heads* may be applied to them, after the term used for such abrupt valley heads in Florida. The issuing waters at Donaldson and Hamer caves of the Spring Mills State Park have produced such gulch-like steep-heads. Shirley and Leonard springs, four miles southwest of Bloomington, Monroe County, occupy two excellent examples of steep-heads where the waters issue through talus with little evidence of cavern mouths. Occasionally an underground stream issues from the side of the valley near the base of a steep-headed notch, to which the term *spring alcove* may be applied. The short steep-head at Hamer Spring of the Spring Mills State Park may be designated as a spring alcove. The steep notch at the rise of Stampers Creek, three miles southeast of Paoli in Orange County, and the notches at the Avoca and Popcorn springs in Lawrence County, are excellent examples of spring alcoves. Numerous steep-heads and spring alcoves are characteristic of hundreds of springs issuing from the Beech Creek limestone of the Crawford upland area west of the sinkhole plain. The springs issuing at Rays Cave and Sexton Spring in eastern Greene County, and at "The Gorge" southeast of French Lick occupy such spring alcoves made by waters coming from the Beech Creek limestone where massive sandstone is exposed above as a heavy over-hanging brow.

Long continued flowage of waters underground in limestone terrains has developed natural subterranean runway voids known as *caverns*. Some of them are of great size, and, no longer occupied by underground streams, are attractive scenic features within themselves. The smaller caverns usually show very clearly that their development took place along joints and bedding planes in the limestone strata. The joints and bedding planes are systematic, three-dimensional slits which may be occupied by thin films of subsurface water, and which offer opportunity for forced passage under a hydrostatic head. Waters from the surface enter them and selectively enlarge and develop them into initial cavernous routes of discharge, where the waters move through the limestone from higher to lower levels of drainage. Once selected out from the original grid of joints and bedding planes, they offer easy lines of passage of surface rainfall and run-off as underground drainage routes in preference to surface routes of drainage. If these premises are true, large caverns have been hollowed out by the solutional action of large quantities of water which have flowed through them. Some students of cavern development believe that the deep ground waters themselves have developed the caverns of limestone areas, while others believe that in-fed waters from the surface have developed them. Many large caverns are the underground channel routes of water drainage in limestone areas, and in times of heavy rainfall receive and convey great floods of water through their voids. In periods of low water many of these underground drainage conduits may be entered and explored. (Fig. 10.)

Few caverns may be explored great distances, as rock falls and other features obstruct the passages. The Donaldson cavern system of the Spring Mills State Park has been explored and mapped by Scott (1909) for 9,127 feet, which is perhaps only one-third of the underground distance back to the sink of Mosquito Creek where the cavern probably heads. Trinkle Cavern, near Hardinsburg, Washington County, is the

Fig. 10. View in Trinkle Cavern showing a mud bank made by the storm waters of underground Sinking Creek, beneath U. S. Highway 150, one mile southeast of Hardinsburg, Washington County. 9,300 feet of the route of this stream-coursed cavern have been mapped.

route of the lower section of underground sinking Creek. It was mapped by Bates (1932) for a distance of 9,300 feet, which appears to be about one-half of this underground section of Sinking Creek. The writer has entered and mapped (1932) only a small fraction of the many miles of the underground course of Lost River. Addington (1927) was able to explore and map only about 850 feet of the well-known Porters Cavern in northeastern Owen County, though he clearly shows the main cavern to be a relatively simple drainage conduit about 2,000 feet in length. Fidlar (1935) explored and mapped the complete route of Old Town Spring Cavern, near Marengo, Crawford County, from its mouth to its beginnings under a sinking stream, a distance of 3,500 feet. Only primitive, undeveloped tubes, defying exploration, were found to extend beyond the clogged entrance holes of the surface floods from the sinking stream above the explored end of this cavern. Blatchley (1897), in his well-known "Indiana Caves and Their Fauna," gives the characteristics of 17 caverns and the mapped routes of seven of them. The explored routes of only six of them exceed 1,000 feet, and only the famous Wyandotte

Cavern was found to exceed 3,000 feet in length. Many of the caverns explored and mapped are only fragments of far more extensive conduits, but obstructions prevented further exploration in them.

Some caverns are single-route conduits, while others are a complex of routes. Dry caverns very frequently have two or more levels of development, or are *galleried caverns*. The cavern galleries may be directly above or below each other or they may wander away. Three cavern galleries have been commonly noted, and as many as five have been rather vaguely ascertained. The tiered cavern systems appear to be partly dependent upon development at successive levels because of stages of down-cutting of the outside valleys into which the cavern drainage was discharged, but relative ease or opportunity of development in certain layers over others is also a factor in multiple cavern levels.

Many dry caverns still indicate that they were once the courses of underground streams. Marengo Cavern of Crawford County is such. Its silt-covered, current-marked floor clearly indicates the former presence of a free flowing stream. Its floor is now only 25 feet higher than the outlet of an underground stream of considerable size which enters the surface drainage near-by. The great Wyandotte cavern system has long routes of stream deserted channels, the main floors of which are 65 feet above the near-by Blue River. While the deserted stream floors in these magnificant caverns receive little attention from the casual visitor, they are significant aspects of the great routes themselves in which the more attractive decorative features have been formed. These long cavern voids were once the routes of coursing waters which flooded through them in a manner similar to streams in surface channels. They, too, had periods of quiet flow and periods of boisterous flood, dependent upon rainfall and run-off fed into them. Perhaps the waters which formerly coursed through Marengo Cavern came from parts of Cider Fork valley, while Wyandotte carried part of the waters of Blue River itself for a long period before special conditions favored a relatively rapid down-cutting of the surface valley, and the waters were shunted away from the shorter subterranean course which is now high and dry and only partially explored. Little investigation has been made with respect to the drainage condition under which our larger dry caverns have been developed. This fertile field of geomorphic study is a standing challenge to the problem of cavern development in the karst terrain. The long dry caverns certainly once carried surface drainage waters similar to the wet and frequently flooded cavern conduits of which the underground routes of Stampers Creek and Lost River are examples.

Natural bridges are occasionally present in karst regions. They are almost wanting in the Indiana karst. Addington (1928) has described two rather insignificant natural bridges, located a short distance north of McCormicks Canyon State Park in Owen County, as the Litton natural bridges. These small arches are the remnants of the roof rock of a shallow cavern where two small windows have been developed by collapse near the terminous of a small cavern tunnel known as Wolf Cave. I have no knowledge of other natural bridges in the Indiana karst, though a few natural arches or bridges are developed elsewhere.

Subterranean cut-offs form an assembly of underground drainage or karst features of more than usual interest. A subterranean cut-off is an underground diversion of a stream beneath a meander spur. It is composed of a swallow-hole into which a stream sinks, a subterranean tunnel, and a rise or resurgence of the diverted water on the opposite and downstream side of an intrenched meander. No fully completed subterranean cut-offs are known in the Indiana karst, but at least five developing cases are known. Malott (1919) has described a well developed subterranean cut-off along Clifty Creek in the American Bottoms region of eastern Greene County, about one and one-half miles north of the village of Koleen. Another has been described in considerable detail by Malott (1922) along Indian Creek, about nine miles west of Bedford in western Lawrence County. This developing subterranean cut-off involves the sink, the passage, and the resurgence of the low waters of Indian Creek beneath the neck of a large compound meander spur. The subterranean route is only one-fourth of a mile in length, while the meander route of the surface channel is more than three miles in length. The developing subterranean route well illustrates economy of distance.

Thornbury (1931) has described two developing subterranean cut-offs along the deeply intrenched Bogard Creek and Little Blue River in central Crawford County, about three and one-half miles southeast and four and one-half miles south of English, respectively. The one along Little Blue River, known as the Carnes Mill cut-off, is of more than usual interest. The intrenched meander loop is a short one and the neck is very narrow with only 200 feet of separation. The natural tunnel

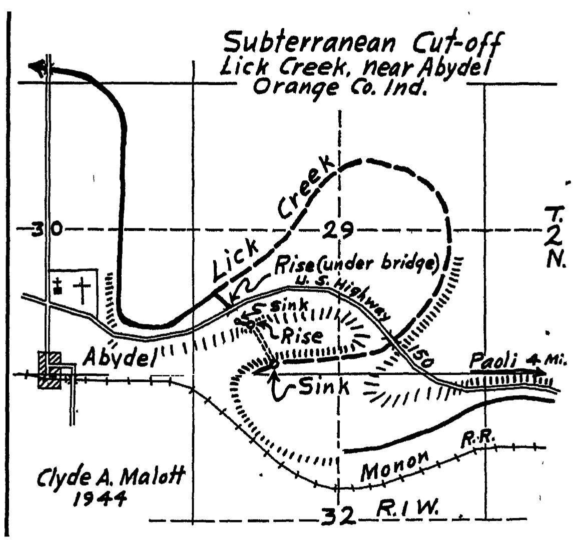


Fig. 11. Sketch showing the location of a developing subterranean cut-off along Lick Creek, about four miles west of Paoli, Orange County. The resurgence of Lick Creek takes place beneath a bridge on U. S. Highway 150.

was formerly used as mill race in the operation of a small mill. It appears that subterranean perforation here is serving as an aid to valley intercision in which a surface diversion will probably take place before total subterranean diversion can be completed.

A more readily available and undescribed subterranean cut-off is developing through a meander neck of Lick Creek on the well known Ballard farm along U. S. Highway 150 between Paoli and West Baden in Orange County. The resurgence of the diverted waters of Lick Creek appears first as a spring-like rise on the north side of the meander spur less than 100 yards from the highway. The waters then sink again in swallow-holes, and again rise under a highway bridge. The bridge, with a considerable stream in a normal channel on one side and no stream or channel of any kind on the other, presents an anomalous situation among highway bridges. (Fig. 11.)

An adequate discussion of the significant aspects of the Indiana karst requires some consideration of the Crawford upland area west of the general sinkhole plain, where rugged sandstone ridges separate deep-set valleys with their floors developed in limestone. Here, shales and heavy bedded sandstones overlie the limestone and compose the rugged ridges. The deeply intrenched valleys, however, penetrate into the soluble limestone and karst features have been developed in them, producing *karst valleys*. The normally developed tributaries with their dendritic arrangements reach from the standstone hills into the karsted valleys where their waters are lost in swallow-holes. The tributary streams are the dismembered distal branches of former trunk streams which once descended the main valley in normal stream alimentation. In the floors of scores of these valleys there are no signs of a trunk stream, the floors being completely characterized by sinkholes and other karst features. Many of them, however, have dry-bed stretches which terminate in swallow-holes or which discharge surface storm waters down the lower sections of the karst valleys. Some of the dismembered side valleys terminate abruptly in deep-sunk individual courses, producing blind valleys. The sinking waters of the karst valleys in many cases are directed through underground routes completely away from the valley into the deeper surface streams adjacent, but commonly the underground drainage comes to the surface in the lower part of the same valley, appearing as a rise or karst spring. Occasionally karst windows reveal short sections of the subterranean streams.

Karst valleys characterize at least 400 square miles of the western hilly margin of the karst terrain in southern Indiana. They occur west of the dissected Chester escarpment and west of the sinkhole plain proper. Some of them are quite broad and present hemmed-in small karst areas west of the main area of the karst plain itself. Caverns are far more abundant and much more readily available in the karst valley areas than in the sinkhole plain proper. Karst valleys are numerous in western Lawrence, Orange, western Washington, northeastern Crawford, and western Harrison counties. Ripperden, Grassy, Walnut, Moberly, Brushy and Hancock valleys of western Harrison County are well developed karst valleys perched above Indian Creek and Blue River into which

their underground drainage is discharged through large artesian rises or springs. Cider Fork valley of northeastern Crawford and southeastern Orange counties has many undescribed characteristics of underground drainage awaiting study. Sinking Creek Valley of southwestern Washington County, with the longest mapped single-course cavern in Indiana, has received some study by Bates (1932). Mahan Valley, a partial tributary of Stampers Creek in Orange County, and the Dry Branch system north of Orangeville near the rise of Lost River, possess interesting surface and underground features which as yet have not been published. Beaver Valley, along the B. and O. Railway and State Road 60 and U. S. Highway 50, west from near Mitchell to Huron in southwestern Lawrence County, has had more than 30 square miles of its drainage directed from under it to East White River on the north and to Lost River on the south, both of which are many miles away. It does not recover its own lost waters. At least 100 of its tributary branches have been dismembered and terminate in individual swallow-holes, and finally its beginning trunk, far down its valley, is itself swallowed up one-half mile east of the village of Huron. It contains the unusually interesting Salts Cavern through which waters are conducted to the Lost River system, and Connerly Cavern which carries waters beneath a high ridge from one part of the system to another. The hidden drainage of this remarkable valley is virgin territory awaiting detailed study, like that of much of the Indiana karst.

The features described in this brief survey of the Indiana karst are features dependent upon the solvent action of the waters received from the surface. Systematic solution has so riddled the limestone terrain that the waters of storm and stream are diverted from the surface to underground routes. Sinkholes, sinking streams, underground streams, caverns, great springs, and the like, are co-related phenomena of subterranean drainage, and they compose the significant features of karst terrains wherever they are.

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ANTHROPOLOGY

Chairman: G. K. NEUMANN, Indiana University

Mr. J. C. Householder, Indianapolis, was elected chairman of the section for 1945.

An Archaeological Survey of Monroe County

W. R. ADAMS and W. B. ADAMS

A few years ago in answer to a request for information the statement was made that whatever Indian material had been found or collected in Monroe County was without published record. We were told that someone should work toward this end. As a side line to business and field trips we started listing the locations of sites on a topographic map or plat book, filling out a sheet of descriptive data for each site, and making a surface collection of artifacts.

Monroe County lies southwest of Indianapolis in the group of counties bounded by the East and West Forks of White River. It is approximately rectangular in shape, extending twenty-four miles north and south, by seventeen miles east and west. On the north it is bounded by Morgan County; on the east by Brown and Jackson; on the south by Lawrence; and on the west by Greene and Owen counties. The county lies below the glacial boundary and contains little level ground.

Originally the whole of this county was heavily wooded. Even today there is much land in forest and more is being acquired by the state for forest preserves. Farmers are realizing, more and more, that much of the land must be grazing land. Also it should be remembered that practically all of these sites have been under cultivation from forty to one hundred twenty-five years. Since we covered only the ground that had been under cultivation at one time or another, the number of sites reported must not be taken to mean the number of existing sites in the county. These facts make it imperative that this survey if to be finished must be done without further delay.

Sites range from the lowest point above high water to the highest point in the county, with an elevation difference of around 400 feet. The rock strata in this county slope to the southwest at the rate of one foot per hundred. Since there are chert-bearing strata both underlying and overlying the Salem limestone (Indiana Oolitic) which outcrops from the northwest corner of the county to the middle of the south county line, numerous outcroppings of chert appear. Although chert was the most widely used in this area by the Indians, it should be stated here that there was extensive use of non-local stone.

Monroe County consists of four east and west tiers of three townships each, or a total of twelve. Marion, Washington, Bean Blossom, Bloomington, and eastern Richland are drained by Bean Blossom Creek

and its tributaries. This creek enters the West Fork of White River at the extreme northwest corner of the county. Benton, Salt Creek, Polk, eastern Clear Creek, and southeastern Perry townships are drained by Salt Creek and its tributaries, which enters the East Fork of White River in Lawrence County. Perry, eastern Van Buren, eastern Indian Creek and western Clear Creek townships are drained by Clear Creek which enters Salt Creek a quarter of a mile before it leaves the county at its southern boundary. Northwestern Richland township is drained by Raccoon Creek which enters the West Fork in Owen County. Western Van Buren and southwestern Richland are drained by Richland Creek which enters the West Fork in Greene County. Indian Creek, a tributary of the East Fork drains western Indian Creek and southwestern Van Buren townships.

In Bean Blossom township we have as yet no sites, and in Washington to the east, only one.

Marion township, in the extreme northeast of Monroe County has three sites (68;85;87) while in Benton, the next township to the south there are five (40;41;44;58;84). One of these locations furnished a full-grooved axe indicating Shell Mound, Adena, or Greene County Woodland relationships; while a bilunate type banner-stone found there has not as yet been associated with any known culture. At another of the locations a cache blank of Wyandotte flint similar to those from the Hopewell site was found.

In Bloomington township, there have been six locations recorded (35;43;45;62;93;94) at one of which was found a three-quarter grooved axe of Woodland affinity.

Richland has one site (28) where again was found a full-grooved axe pointing to Shell Mound, Adena, or Greene County Woodland.

In Van Buren, the next township to the west, there are fifteen locations (3;4;5;31;37;38;39;49;52;53;54;55;56;57;104). One very productive site (56) yielded an elliptical gorget of a general Adena horizon tentatively dated as 900-1200 A.D.; a developed Adena gorget; and a curved base platform pipe indicating a developed Ohio Hopewellian relationship dated perhaps to the late thirteenth century (1200-1300 A.D.). On site 52 a triangular point indicative of the Mississippi Pattern was found.

Perry township located east of Van Buren contains the greatest number of locations with a total of twenty-five (7;13;18;22;23;25;B 26;27;30;33;60;61;63;64;68;69;70;71;74;78;90a&b;98;100;101). Three of these sites are of special interest: No. 71 with stemmed points indicating Adena and Shell Mound; No. 22 with stemmed points and a cylindrical pestle characteristic of Shell Mound; and No. 64 with five Adena type gorgets. Site 90 yielded another Mississippi projectile point.

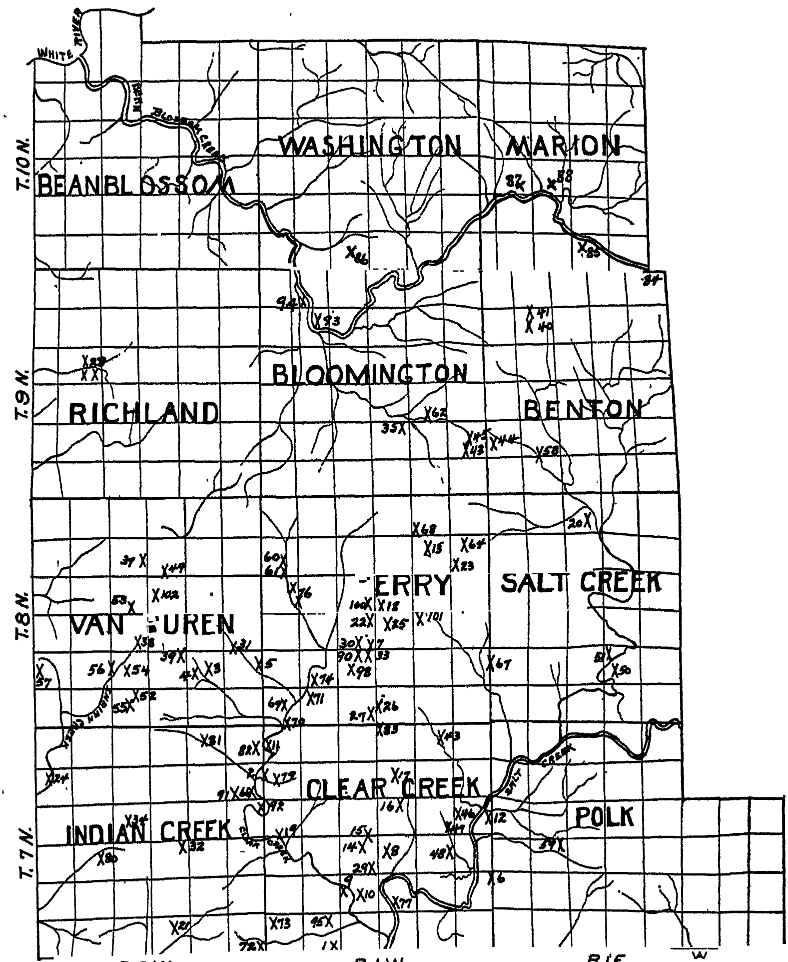
In Salt Creek township to the east there are four sites (20;50;51;67) producing generalized Woodland points, and one (50) a Mississippi arrow-head.

In Polk township the most southeastern in the county we have two sites (59;6).

In Clear Creek, the next township to the west there are twenty-two sites (1a,b,c;8;9;10;11;12;14;15;16;17;19;29;42;46;47;73;77;79;83;95). One of these yielded projectile points of Shell Mound type; another furnished points of general Woodland and Hopewellian types.

To the west in Indian Creek we have located thirteen sites (2;21;24;34;42;66a&b;72;80;81;91;92) at one of which (80) bannerstones of both

MONROE COUNTY INDIANA



Hopewellian and Shell Mound types have been found, while a fourth Mississippi point comes from site 91.

Due to the fact that the artifacts represent solely surface material and that only a limited area is considered here, the conclusions dealing with cultural affiliations are necessarily only suggestive at this time:

(1) As only one Folsom point has been reported from Monroe County, this complex is probably poorly represented. An explanation may be found in the fact that this complex, being part of a plains culture, may have skirted this wooded region keeping to the north to reach Ohio.

(2) Artifacts characteristic of the Shell Mound people appear in this county but as yet cannot be clearly differentiated from generalized Woodland material to which the majority of the artifacts belong. Shell Mound sites are found both toward the south and southwest of this region along the Wabash, Ohio, and White Rivers.

(3) The Adena and Hopewellian manifestations, which follow chronologically, appear in Greene County to the west. Pure sites of related material have so far not been identified in Monroe County. The absence of these entities can be correlated with the absence of mounds and pottery. The answer lies in the excavation of the sites yielding the developed Hopewellian artifacts.

(4) Four sites (50;52;90;91) have yielded small thin triangular projectile points, typical of Upper and Middle Mississippi sites. Judging from the presence of Upper Mississippi (Fort Ancient Aspect) sites in Marion, Ohio, and Dearborn counties these points probably can be classified as belonging to this complex. The nearest large Middle Mississippi site is the Angel site near Evansville. Here again the answer awaits excavation of these sites.

The Oliver Farm Site

J. C. Householder, Indianapolis

The Oliver Farm Site is a large Indian village on White River in Marion County, Washington Twp., Indiana. It lies within a large U-shaped bend of the river, being surrounded by water on the east, south and west. Across the river is the Bosson Site. Much of the site's value to the present day archeologist has been destroyed by the unknown number of floods which for many, many years have swept across its floor from east to west; but even yet over a number of recent years the site has yielded a vast amount of archeological material: pottery, flint objects, a relatively small amount of stone artifacts, a very little worked bone, a few slate problematical pieces, no worked shell, no copper, and only a very few articles of the White man's provenience which are obviously of a very late period and show no relationship whatsoever with the archeological material. The Oliver Farm Site is typical of a number of other sites found in Marion County along White River and its tributaries; and the same type of sites have been found upstream along White River into Hamilton County and down the same river into Morgan County.

The most striking feature observable at the Oliver Farm Site and others of this group is co-mingling of Fort Ancient and Woodland types of pottery sherds found in great profusion on and beneath the surface of the ground. However, this does not hold for all the sites examined by this writer along White River and its confluent streams, notably Fall Creek, in Marion County, and up and down stream from the Oliver Site into adjacent counties. In all something between fifty and sixty sites, including villages, camp sites, and burial places, have been found in this area. Considering the relatively large twelve sites upstream from the Oliver Site in Marion County and on into Hamilton County, five of these sites have produced this combination of Fort Ancient and Woodland types of sherds, while seven of them are strictly Woodland insofar as surface evidence has shown. Of the larger sites downstream from the Oliver Farm and on through Marion County into Morgan County, out of a total of twenty-seven such sites, fourteen exhibit this combination of Fort Ancient and Woodland types of sherds. Thus, out of thiry-nine sites we find that practically one half of them (19) have been discovered to have this observable feature.

Concerning this feature on sites farther up and downstream beyond the limits mentioned above and outside the territories worked by this survey, we have endeavored to gather information by correspondence, but without success.

In Morgan County the Duckworth Farm Site is a large village whose assembly of material shows no Fort Ancient sherds, and in this characteristic as well as in the other archeological material found here, is typical of this group of sites in this area.

Listing of Material from the Duckworth Farm Site:

No copper
No worked shell
Cord-marked, grit tempered sherds
Scrapers, "thumb-nail" type
Broken flint drills
Stone celt (1)
Stone axes—none found by this writer
Rough stone pestle, center-pitted in base (1)
Cupstone, cupped on both surfaces (1)
Unfinished slate butterfly bannerstone (1)
Small pieces of worked slate—broken problematical objects (2)
Flint blades (2)
Triangular points (2)
Many stemmed and notched projectile points, including 3 with serrated edges
Many flint chips
Flint blanks and turtle backs

As the listing of the material culture found at the Oliver Farm Site will indicate, it was inhabited by people who had some contact with other groups. In addition to Fort Ancient pottery decorations, the presence of a small but interesting variety of bone work, and the predominance of triangular points are significant.

Listing of Material from the Oliver Farm Site:

No copper
No worked shell
Pottery: Woodland decorated rims and cord-marked body sherds, grit tempered; Fort Ancient rims with decorations on cord-marked or on smoothed shoulders running into cord-marked bodies, usually grit tempered; some shell tempered sherds, same thickness as the grit tempered sherds; a few shell tempered and about the same number of grit tempered broken handles only. An interesting feature is observed in the form of the vessels from this site we have been able to reconstruct. Of the two pots wholly or partially reassembled, one has a flat globular body, the other a semi-flat rounded body. Both of these vessels have smooth undecorated rims, and cord-marked shoulders and bodies; and both are grit tempered.
Scrapers: various types including "thumb nail" and bunts
Small flint drills, with expanding base
A very few stone celts
Stone axes (2)—1 is a very crude double grooved axe
No pestles
No cupstones
Banded slate gorget (1)—center perforation, straight base, concave sides and pointed end: representing the Turkey Foot-totemic

emblem of the Unilachtigo (Turkey) tribe of the Lenape, (Delawares).

Flint blades

Triangular points: predominent

Stemmed and notched projectile points

(Some serrated forms in both triangular and stemmed)

Slate discs

Slate rubbing stones

Bone awl, double pointed (1)—with 7 notches on 1 edge

(A very few other bone awls)

Bone beamers

"Green corn" scrapers

Polished small animal tooth, unperforated

Antler tips

(A small amount of bone work in proportion to other material)

A skeleton was found on the floor level of the site. It was lying on its back, the knees drawn up to the pelvis. Georg K. Neumann has examined the skeleton, and reports it to be of the Sylvid type, typical of the skeleton material found in the northern foci of the Fort Ancient Aspect, and representative of the physical type of the Indians found in northeastern United States, and represented by such tribes as the Delawares, Miamis, Seneca, and the Siouan tribes of the east. (Georg K. Neumann: Letter, October 13, 1944.) The skeleton of a typical Indian dog, the same breed as that found with prehistoric remains all through the Middle West was found on the site. (Georg K. Neumann: Letter listed above.)

We have been working with material found during surface surveys plus a limited amount of excavating on these sites in Marion and adjacent counties in central Indiana. As to whether or not future excavations of some of the more important units will show stratigraphic or other evidence accounting for the discovery of the two pottery types (Fort Ancient and Woodland) we would not venture to say. The writer has long pondered this question: Where is the evidence to suggest that Fort Ancient and Woodland culture bearing groups lived on these sites contemporaneously? Certainly Woodland culture material predominates throughout the area. It is possible that Woodland potters acquired from neighbors the distinctive Fort Ancient rim and shoulder decorations found on these sites, and here made the combinations in such quantities as to make this feature so notable. With the exception of a very small percentage of shell tempering and an equally small percentage of smooth finished thin sherds, the overwhelming majority of the pottery material is of the well known so-called Woodland type, cord-marked, grit tempered, medium as to thickness, and of a hardness ranging from 2 to 2.5.

Or, does this pottery complex, plus an increased proportion of triangular points, and the addition of some bone work suggest a Fort Ancient component here at the Oliver Farm Site and at other similar sites in the area? And yet, furthermore, note that the shape of the restored pottery vessels suggest Middle Mississippi influence. Actual

handling of the material over a long period of study suggests the probability that the actual difference is more apparent than real, and that cultural borrowings have raised a typical northern Woodland semi-sedentary culture to the status of a sedentary culture predominately of the same pattern.

All of our work on the Oliver Farm Site has been made possible through the very enthusiastic cooperation of Mrs. Hugh (Olive Oliver) Carpenter and Mrs. J. B. (Martha Oliver) Dougherty, and the kind assistance of Mr. Frank Dawson.

Since this paper was prepared for publication, we have received a letter from Mr. E. Y. Gurnsey, Bedford, Indiana concerning the Sites downstream outside the territories mentioned above. From this letter dated November 1, 1944, we quote:

"It is true that the same combination of Fort Ancient and Woodland types of pottery sherds is characteristic on many of the Lawrence County Sites. The Brown Site, at the mouth of Guthrie's Creek, covers an area of thirty acres, and is very definitely Fort Ancient in as much as Fort Ancient and Woodland types of pottery are found in great perfusion on the surface. The same is true of the Williams Site, near the village of Williams. These are the two largest Sites I have so far encountered. There are dozens of other Sites on the terraces of the east fork of White River in Lawrence County with the same combination of Fort Ancient and Woodland types of pottery sherds.

The so called "quilloche" motif does not appear in this area. There is a decided "Southern" influence in the ornamentation in general."

Here we find the same combination of Fort Ancient and Woodland types of pottery. But Mr. Gurnsey does not mention other archeological materials. It is reasonable to believe that these Sites are typical of the Oliver Farm Site. A comparative analysis of all the archeological material from the large Lawrence County Sites with that found at the Oliver Farm Site will be of much value, in the hope of being able to extend southward the area range in which is found the material complex discovered at the Oliver Farm Site and similar Sites examined by this survey.

Tentative Speculations on the Chronology of the Walam Olum and the Migration Route of the Lenape

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There is reason to believe that four dates mentioned in the Walam Olum may be closely approximated:

First: The following statement occurs on pages 36 and 37 of the *History of the State of New York*, by Yates and Moulton, Vol. I, Part 1, published in New York in 1824:

> "The Rev. Mr. Beatty, in his mission from New York in 1776, [1]"to the western Indians, received from a person whom he credited, the following tradition, which he heard from some old men of the Delaware tribe. That of old time their people were divided by a river, and one part remained behind; that they knew not for certainty how they came first to this continent, but gave this account, viz., that a king of their nation when they formerly lived far to the west, left his kingdom to his two sons; that one son making war upon the other (p. 37) the latter thereupon determined to depart, and seek some new habitation; that accordingly he set out, accompanied by a number of his people, and after wandering to and fro for the space of forty years, they at length came to the Delaware River where they settled three hundred and seventy years ago. The way they kept an account of this was by putting a black bead of wampum every year since on a belt of wampum used for this purpose."

We may believe with pretty good reason that reaching the Delaware River is recorded in lines 27 and 28 of Song V.

V, 27 When Red Arrow was chief, they were so far downstream that tides could be felt.

V, 28 When Red Paint Soul was chief, they were at the Mighty Water.

If our premises are correct, that date would be about 1406.

Second: Lines 39 and 40 of the same song record that: "Whites came floating from the east." Cabot coasted along those shores in 1498 and Verazano in 1524, so we may fix that date at about 1500.

Third: Song V ends: "When the Whites came from north and south," i.e., about 1622-1634.

Fourth: The "Fragment" begins where Song V ends, and the dates of the consecutively mentioned chiefs may be identified by history. In this "Fragment" the year 1800 can be approximated.

The period recorded from the year 1634 to 1800 by the "Fragment" thus presumably covered 166 years with twelve chiefs mentioned, or 13.82 years per chief. From Cabot until the coming of the Whites was 134 years with thirteen chiefs, or 10.03 years per chief. From the arrival of the Lenape at the Delaware until the coming of Cabot was 104 years, with seven chiefs during that period, or 14.85 years per chief. For the total of 404 years there were 32 chiefs mentioned, an average of 12.6 years per chief. The fact that the average of these three periods is not

[1] See his Journal of two months' tour with a view to promoting religion, etc. By Ch. Beatty, A.M., London, 1768.

very different from each of the three tends to substantiate the correctness of both the datings and the length of the period of each chief's rule.

In calculating the elapse of time by this 12.6 year chief average, there is always the question as to whether or not the chiefs were always successive, or in some cases contemporary—some war and some village chiefs. There are a few instances where this is possible but almost invariably the wording clearly indicates that the chiefs are listed in chronological order, even in the several cases where two chiefs are represented in the same pictograph. Neither does a study of the names clearly indicate the identity of war chiefs and village chiefs.

It also seems that even if an occasional contemporary chief's name did slip in, the number of these occurring in the 404 datable years would approximate the same proportion as in the years previous to them.

Of course it may be that the farther the list runs back into the past, the more omissions occur, but all in all the 12.6 year interval per listed chief appears to be as close an estimate as can be made to form a basis for the chronology of the Walam Olum.

Adopting this average of 12.6 years per chief and extending the dates back at this rate, we have the Lenape crossing Bering Strait about 550 A.D., at Snow Mountain between 800 and 900, crossing the Mississippi (?) near 1050, spending the years between 1200 and 1300 on "the middle reaches of White River," and crossing the Alleghenies about 1350.

Speculations on the Route of Migration

Basing our speculations upon a new and better translation of the Walam Olum made by Dr. C. F. Voegelin, of Indiana University, it seems quite certain that Turtle Island in Song III, "Where the land slopes north," (III, 3) must have been northeastern Asia. Lines 16, 17, 18 in Song III pretty closely describe the passage of the Lenape across Bering Strait in both text and pictographs. Further, III-18 tells of their ascent of what must have been the Yukon River, of which Hrdlicka says on page 81 of the 46th Annual Report of the Bureau of American Ethnology, "The great and easily navigable river, extending for many hundreds of miles from west to east, could not but have played a material part in the peopling of Alaska, and quite probably in that of the continent. . . ."

Since many of our modern roads and railroads followed the trails and passes first used by the Indians, it is reasonable to suppose that in the southern migration of the Lenape from the head of navigation on the Yukon to the warmer portions of "Snake Island," their pathway might have approximated the route of the modern and celebrated Alaskan Highway, and, as a matter of fact, some of the verses fit into this picture. If this theory is correct, they helped develop the Great Northern Trail, swinging down through the provinces of Yukon, British Columbia and Alberta, through the sites of Edmonton and Calgary, continuing diagonally across Montana, bearing to the southeast. The old trail bore south again after crossing the extreme northeast corner of Wyoming, passing along the western edge of South Dakota and Nebraska to join the Santa Fe Trail.

As we proceed, we hope to develop some sound reasons for believing that the Lenape followed a more western path in their migrations than has hitherto been thought.

IV, 1 reads, "Long ago, people like the Lenape were in a forest by a lake." The map reveals several large lakes on the border between Yukon and British Columbia and elsewhere in the neighborhood of the Alaskan Highway.

IV, 8 ". . . White Owl was chief at the forest land." Great forests cover British Columbia and southwestern Alberta.

IV, 12 ". . . narrates a split in the company—some going east under Chief Beaver and some going south with Chief Bird." This very well may be the point where the eastern Algonquins separated from the central tribes, the former passing eastward north of the Great Lakes and proceeding "far from the buffalo country" (IV, 14).

There are some lines that are difficult to fit into any theory regarding the route followed, such as IV, 13. "In the Snake Land, in the southern land, the great land which extends along the shore." Is the west coast of North America being referred to, or is the shore of the Great Lakes meant? Since the pictographs show the water glyph to the west, we take it to indicate the west coast.

IV, 16. "The Shamans, the Snakes, the Blacks, and the Stonies." Previously these tribes have been identified with several supposed to be in the Lake Superior region, but in reaching this conclusion, consideration has not been given to the fact that this meeting took place about 650 A.D., and at that period these tribes were probably far from their historic habitat.

IV, 23. If our theory of the route of the Lenape is correct for the location where Red Paint Person invented drawing (on the north edge of the berry country), should we not find petroglyphs, possibly resembling the Walam Olum figures in southern Alberta, southeastern British Columbia, Montana and Wyoming? It would be well to have this investigated.

IV, 24. "One Who is Cold went south to the berry country." Former translations speak of corn which is incorrect. While blueberries, bilberries, and Juneberries grow in the coast ranges from northern California to Alaska, the main "berry belt" extends across lower Canada and extreme upper United States, between latitudes 45° and 55°. Here the Lenape were, in, say, 750.

IV, 28. "It was not raining and there were no berries, so they went over to the east where it was wet." The Great Northern Trail leads to the east here too. In our chronology, based upon 12.6 years per chief mentioned, this would have been about 825 A.D. Unfortunately there are no tree ring records for Montana and the land to the north to check against this drought of approximately 825, but the tree ring record in the American Museum of Natural Science in New York in the form of Douglas photographs shows extremely little rainfall among the big trees of California from 650 to 770, the lowest years being 650, 720, and 770. The latter date is not too far away from our tentative chronology to give food for thought. Tree ring records from the Southwest show drought periods from 738 to 744, from 791 to 797, and from 823 to 825.

Both of these areas are too far away from Montana to draw accurate conclusions, but it is thought that the long range rainfall of that region would more closely resemble that of California than the Southwest.

IV, 29. "By the good hills and along the plains, bison were beginning to graze." Mention of plains and bison would point to central or southeast Alberta, southern Saskatchewan and northern Montana.

At this point there is frequent mention of an enemy tribe, "the Snakes." It may always or only occasionally simply mean enemy. That the pictographs always show a special head ornament for Snakes in the same manner as for other tribes makes it likely that some special tribe or stock is meant. The Shoshone were known as Snakes and they might very well have been in the localities we have been discussing. Also the Sioux were called Snakes and they might have been in that region.

IV, 33. "Those at Snow Mountain were happy and made One Who is Beloved chief." There is a Snow Mountain in Park County in southern Montana just north of the Yellowstone National Park. The Big Horn Mountains in north central Wyoming are known as the White Mountains by the Indians.[1] The Medicine Bow range in southeastern Wyoming has been known as the Snowy Range and the highest peak of these has been called Snow Peak.[2] It is very probable that these names have come down to us from the Indians as so many of the place names of our country have. It is quite possible that this is the region referred to in the Walam Olum. Our time schedule would place them here in 800 or 900. The archaeological culture known as Signal Butte II is Woodland and rather close both in time and space. Possibly a relationship may be discovered here.

One strong reason for preferring the more western route for the Lenape migration is a statement on page 533 of Heckewelder's *Narrative* which reads: "The Lenape (the Delaware) resided many hundred years ago in *a far distant country in the western part of the American continent.* For some reason they determined to migrate eastward, and accordingly set out in a body. After a very long journey and many nights encampment by the way, they at length arrived at the Namesi Sipu (i.e. the "River of Fish," the Mississippi) where they fell in with the Mengwe (the Iroquois)."

IV, 34. "Once *again* they were in a settlement by the Yellow River, where berries were abundant among the rocks and stones." The word "again" is significant, for the Yellow River is the Missouri or the Yellowstone and to get from the north into central or eastern Wyoming, the tribe would have had to cross these rivers once, and now on their long trek to the eastward they reach the Yellow River "again." From southeastern Wyoming to the Missouri their route may have approximated the eastern portion of the Oregon Trail. Surely it is more than a coincidence that our theoretical route of migration passes through regions so aptly described in the text and in the same sequence.

IV, 49. "They separated at ? River; and the ones who were lazy returned to Snow Mountain." Due to an erasure and a rewriting of the name of this river in Rafinesque's notebook, this is the most confusing line in all the Songs. Through the kindness of Dr. Mason of the University of

Pennsylvania, photographic and handwriting experts were called upon to help solve this problem, all to no avail. As it stands today, the name is illegible and the problem must be solved, if solved it ever be, from some other angle of attack.

With all due respect to theorizing, it seems advisable to give weight to the tradition given us by Heckewelder and to conclude that the river was the Mississippi.

Another indication that the Lenape had once lived in the region just west of the Mississippi is found in line 18 of the "Fragment" of the Walam Olum. Here, after speaking of the plan for returning to Missouri, beyond the Mississippi, it reads: "Near to our ancient seat."

The pictograph for V, 49 also showed a wider stream than in other river symbols, and that it flowed north and south.

The next problem is: Who were the Talligewi? Some light may be thrown upon this question by recalling the territory claimed by this tribe.

Heckewelder[3] and Loskiel[4] state that the whole Ohio Valley at least as far down as the mouth of the Wabash was and still in their time was called Alligewinengk by the Lenape. Their statements have been accepted by Brinton[5] and Mooney.[6]

In Dr. Voegelin's new translation, the Talligewi have been called the Yuchi, but complete proof of the correctness of this theory is lacking now. A projected summer's field work should help settle this question. In this connection it should be noted that Speck says (in "Ethnology of the *Yuchi Indian*," University of Pennsylvania, Anthropological Publications of University Museum, Vol. I, No. 1, p. 13) that the Yuchi sign is the right hand raised level with the head, with the index finger pointing upward, a demonstration indicating affiliation with the sun. This is pretty close to the Talligewi glyph of the Walam Olum—a line from the top of the head extending to the right—eastward—the sunrise.

Schoolcraft,[7] Thomas,[8] Mooney,[9] and Brinton[10] came to the conclusion that Lenape and Wyandotte traditions could be believed; namely, that the Talligewi were the ancestors of the modern Cherokee and that many of the typical earthworks of Ohio and West Virginia owe their origin to these latter people.

Another method of arriving at the proper conclusions of this question would be to learn what tribes were occupying the Ohio Valley at the time of the Lenape invasion. If our chronology is at all correct, the Lenape came into the Ohio Valley around 1100 A.D., and at that time, according to the best archaeological beliefs, the Hopewellian period was just beginning. Who were they? While several tribes may have taken part in the "Hopewell Movement," some signs point to the Cherokee as being one of the participants.

Haywood[11] states that the Cherokees had a tradition relating that "they came from the upper part of the Ohio where they erected the mounds on Grave Creek," etc. Brinton,[12] Cyrus Thomas,[13] and Charles E. Royce[14] repeat this legend and Brinton says further that: "Professor Thomas has shown beyond reasonable doubt that the Cherokees were mound builders within the historic period.[15]

Adair,[16] Brinton,[17] and Loskiel[18] report Cherokee traditions that they once lived on the upper Ohio and its tributaries. The great objection to this Talligewi-Cherokee theory is that as yet no archaeological tie-up has been established. If Adena is early Cherokee, then that tribe must have changed cultural concepts to a large extent in a short time, for the historic Cherokee archaeological traces, including the Peachtree Mound reported on by Setzler, are entirely different from Adena.[19]

On page 60 of his, *A Life of Travels*, Rafinesque says, "At Marietta I went to survey the ruins of the ancient town and monuments of the *Talegawis*," thus with or without sound reason identifying this tribe with the Hopewellians.

V, 2. "Road Man was chief there along the middle reaches of White River." There is a note reading "Wabash" in Rafinesque's own handwriting on this line in his notebook, so the Wabash is one candidate for the honor of being the river in question. The glyph would indicate that the road or river extended north and south.

On De l'Isle's map of Mexico and the United States of 1783 and on an anonymous map published in Amsterdam between 1705 and 1720, and probably other maps, the Ohio River is labeled "Ouabache, in other times called the Ohio or the Beautiful River." This confusion of river names puts forward the Ohio itself as another possibility.

White River in Indiana is the third contender and the Little Miami in Ohio, formerly known as the "R. Blanche," is fourth.

Mr. Paul Weer called attention to an observation by Speck which may permit us to fix the location of the Lenape on the middle reaches of the Ohio; namely, that stone masks are diagnostic of Lenape occupation.[20] Mr. Glenn A. Black, with his usual thoroughness, has made a search of the literature for reports of stone masks in the Mississippi Valley, with the following results: one at Portsmouth, Ohio, one near Lawrenceburg, Indiana, two from Gallatin County, Kentucky just across the Ohio from Lawrenceburg, one in Ross County, Ohio, another from an unknown location in that state, and one in Belmont County, Ohio, just across the river from Wheeling, West Virginia. Lately another mask has been discovered in the Cincinnati Art Museum that probably came from Ohio, Indiana or Kentucky.

Here is a possibility of proving the "middle reaches of White River" to be the middle reaches of the Ohio by archaeological deductions. Unfortunately the problem is not simple, for the stone heads found on eastern Lenape territory are in the round instead of being true masks. While it is reasonable to suppose they are closely related, there is no real proof aside from the fact that the stone masks have exactly the same cast of features as the wooden images of heads illustrated in Dr. Speck's monograph on the Delaware Indians' Big House Ceremony.

Mr. Black thinks there is a possibility that these masks were left by the "Intrusive Mound Culture" and calls attention to the seeming relationship of like traces in the mounds of Greene County, Indiana, Montgomery County, Michigan, several Ohio locations, and in Jefferson and Tomkins Counties, New York.

V, 9, 10. "When Little Frog was chief, many of them went away with

the Nanticoke and the Shawnee to land in the South." The date here would presumably be about 1265 and not inconsistent with the known historic movements of the Shawnee.[21]

V, 14. ". . . was chief at the river of the Talligewi." This location is not very definite for on some old maps[2] the entire Ohio river is marked with this name—not just the Allegheny. The date is about 1300.

Here, too, the Snakes are mentioned again, which almost certainly puts the Shoshone out of the picture and points to the Sioux or some Algonquin tribe.

V, 19, 20, 21. About 1350, they cross the Talligewi Mountains. Why did the Lenape move east? Is it reasonable to suppose any tribe living in the fertile Ohio valley would move over the rough mountains and into a less fertile region unless they were driven out? There is a little indication in the legend that this was the case but the Lenape would naturally not emphasize their defeat.

They probably crossed the mountains through the Juniata-Susquehanna pass where the Pennsylvania railroad runs, or through the valley of the Potomac (B. & O.), or the Kanawha Valley (C & O).

V, 23, 24. About 1380 they go north to live along the Susquehanna. It should be possible to discover some archaeological linkage in this territory.

They then lived in the Sassafras Country, eastern Pennsylvania and New Jersey, and reached tidewater—the Delaware (?)—in 1396 (?).

V, 40. Here they were, too, when the Whites came floating from the east, 1500.

V, 47. At a long, landlocked lake.

V, 50. At the rushing waters.

These two lines have been taken to mean one of the long lakes in New York and Niagara Falls. At this point it is reasonable to believe that we may sooner or later develop the fact that the Owasco sites coincide with the legend of the Walam Olum, both in time (about 1545) and place. William A. Ritchie says,[22] "If we are correct in our chronological surmises (see Plate 4) and in regarding the Castle Creek Focus as the most recent stage of Owasco development, Lenape or Delaware connections are suspect on grounds of territorial overlapping."

This brings us up to historic times and it should be noted again that the order of succession of the chiefs mentioned in the "Fragment" covering the time after 1600 may be verified by history.

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[2] The Lewis Evans map, 1755, shows the Ohio River as the "Ohio or Allegny R." It is so labeled at the mouth of the Wabash. In the "Analysis" which Evans prepared to go with the map, he gives maps, journals, and "narratives of traders" as the sources of his data.

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Migrations and the Origin of the Woodland Culture

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To any anthropologist interested in the problems of the peopling of the New World a number of logical discrepancies become at once apparent when he peruses a distribution map of the varieties of man and compares it with one that gives the distribution of the different smaller cultural entities of the two continents. The one I would like to consider briefly concerns the correlation of the Sylvid morphophyle, that is, a certain physical taxonomic unit, with the Woodland culture in its temporal and spatial relationships.

The physical anthropologist in trying to solve the question of migrations of the twelve varieties of Indians that are commonly recognized, soon comes to the realization that he not only has to deal with migrations, but also with local evolution of varieties from the migrants. Especially is this the case when he attempts to identify the remains which the ancestors of the South American Indians must have left in North America. Nor has the archaeologist been of much help in this respect. All physical anthropologists and archaeologists agree that the New World was peopled by migrants who entered North America by way of Bering Strait and that the South American Indian groups are derived from North American ones. In other words, they came that way, but their remains have not been identified. We may well ask: Where are these remains? They must have left their dead as well as cultural material.

There are two reasons for the neglect to find answers to this question. One is the isolation of interest in North, Middle, and South America; few anthropologists think of their problems in terms of continental scope. The other is that most anthropologists, and especially the older ones, thought that the peopling of the New World occurred over a relatively short span of time and that it was carried out by one race—that of the American Indian.

Let us consider the last of these two aspects first. It only needs to be pointed out that the degree of differentiation into varieties has progressed as far among the American Indian as among the peoples of other continents. To realize this we just need look at the Andid of Peru, the primitive Fuegid of the southern tip of South America, the Prairid Indian of our plains, and the Eskimid of the arctic coast of Canada. In fact, there are no physical traits that would set off all the American Indians from all Mongoloids of Asia. A similar diversity exists in Asia where Paleomongolids such as the Malays, Sinids such as the northern Chinese, Tungids like the Mongols, and Sibirids like the Yenisei Ostyaks differ as widely. For that reason we cannot accept an American Indian race. It is only a geographical term, and these aborigines merely form varieties of equal rank with those of Asia; they are all varieties of the Asiatic subspecies of *Homo sapiens (H. s. asiaticus)*. Once we realize this our

problem becomes somewhat simpler for we can make an attempt to differentiate between the original migrants, whose remains we can expect to find along the route, and in their Asiatic homeland, as well as the specialized groups and hybrid varieties that developed in various regions of the New World.

The older migrants, predominantly dolichocranial varieties, which often have been pooled into a Paleoamerind morphophyle ranking somewhere between a variety and a subspecies, include the Fuegid, Lagid, Margid, and perhaps the Brasilid varieties. The more recent immigrants, sometimes called the Central Brachycephals, on the other hand, include such units as the Andid, Isthmid, and Centralid varieties. Of these the Andids and the Isthmids can be considered local specializations adapted to a mountain and tropical rain forest environment, respectively, while the Centralid variety tends to preserve the migrant type. Another morphophyle that has been suggested in contrast to the Paleoamerind is the Neoamerind. However, this taxonomic unit would not draw the distinction between the earlier Central Brachycephals, the later dolichocranial varieties, such as the Sylvid and Eskimid, and the last commer to the New World, the low-vaulted brachycranial Pacifid of the Canadian Northwest. To this list only the hybrid Pampid variety of Patagonia and the Gran Chaco, and the trihybrid Prairids of our plains need be added. Considering the associations these larger groupings have it would be best to abandon them and just retain the variety names. As a tentative migration sequence I would like to offer the following: Fuegid, Lagid, Margid, Centralid, Sylvid, Pacifid, and Eskimid. These would be the varieties whose remains we could expect to trace north and westward into Asia. The others are probably derived from them.

A parallel manner of reasoning can be followed in the field of archaeology. It is here highly suggestive that we find Folsom points from Alaska to northern Mexico, that we can trace shell heaps with a relatively uniform culture inland as well as along both the Atlantic and Pacific shores from British Columbia and Maine to Tierra del Fuego, that there are remarkable parallels in pottery types between our Southwest and northern Argentina.

In many instances it will be actually possible to follow the migration routes, that is, in those instances where there exists a definite correlation between cultural complexes and physical type in a number of sites. Two cases may be: the linking of the Basket-Makers of the Southwest with the Shell Mound people of the Tennessee Valley, and the San Francisco Bay shell heap people with a coastal group of Peru. At any rate, an examination of the remains, both physical and cultural, of the earlier populations of both continents is called for. Just as spectacular as these linkages is the distribution of certain types of Woodland pottery found from the Ohio Valley to central Manitoba, and then again in the Lake Baikal region of Siberia. Since the Woodland Pattern is to a large extent associated with the Sylvid variety of Indian, the physical data leads us to some speculations on the origin of this cultural grouping.

Within the last decade there have been published a number of papers which deal with the origin of the Woodland Pattern and possible Asiatic

connections. Essentially the eastern United States forms one culture area, in which important time differences manifest themselves. Besides a common background that links the different parts of the continent, a relatively unilinear development of culture has to be recognized for the Southeast. This development was probably twice influenced from Mexico and at least once more from Asia. The only explanation lies in repeated migrations associated with the diffusion of cultural traits from a number of outside centers. In the light of differences in physical types, and certain similarities in culture traits of widely separated regions, this has to be extended to the Woodland Pattern. Some of its origins are widespread and relatively old. Pottery with fiber and granular temper, basket impressions and cord and brush markings probably go back to at least the beginning of the Christian era. It also must be kept in mind that these are farflung traits, being distributed from Alaska to Brazil and from the Atlantic coast to New Mexico.

On the other hand, a relatively late Asiatic-Mississippi Valley connection cannot be denied when one examines the cultural remains of the Angara culture of the Lake Baikal region and the late Woodland remains of the Mississippi Valley. Pottery traits such as the dentate stamp, embossed rim, cross-hatched rim, lip indentation, cord-marking, conoidal base, and body shape are identical. Gouges and chisels, pestles, knives, chipped points, round and pear-shaped pendants, plummets, fish hooks, needles, awls of bone, arrow polishers of sandstone, and ochre-stained skeletons—all tell the same story, leaving little doubt that the late Woodland material is derived in part at least from the neolithic Angara culture which flourished about 2000 B. C. in Siberia. The fact that the Eastern Siouan, Hopewellian, Iroquois, and Algonkin physical type to a large extent differs from earlier also dolichocranial skeletal material is corroborative evidence for this contention.

Brantz Mayer and the Walam Olum Manuscript

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Brantz Mayer, Baltimore lawyer, diplomat, historian, antiquarian, collector of bibliographical Americana, and Civil War veteran, acquired the manuscript copy of Rafinesque's Lenape (Delaware) Indian record the Walam Olum sometime during the decade of the 1840's, and the manuscript was in his possession January 1876. That he also had all or a portion of the either bark or stick mnemonic tally record pictures is a possibility. Through a series of most fortuitous circumstances this material fell into his hands, eventually was "rediscovered" by Daniel Brinton, and the manuscript is now in the archives of the Brinton Memorial Library in the University Museum at the University of Pennsylvania, in Philadelphia.

When Samuel Constantine Rafinesque died in Philadelphia, the 18th of September, 1840, a small group of Philadelphians, among them C. A. Poulson and S. S. Haldeman, attended the sale of his only earthly possessions consisting of books, manuscripts, drawings, specimens etc.; and for practically nothing those gentlemen of science acquired the small portion of material saved for posterity. The great balance, cart loads of it, was scattered on the Philadelphia dumps. Among the items so rescued, those known to be still in existence have been gathered up and are now housed in the libraries of a few of our larger institutions of learning.

From the *American Journal of Science and Arts*, known popularly as Silliman's Magazine after its editor, Benjamin Silliman professor at Yale College, (vol. 42, New Haven, 1842: page 287) we discover that C. A. Poulson of Philadelphia and S. S. Haldeman (at that time) possess many of Rafinesque's unpublished MSS. and drawings. This statement occurs in Haldeman's article appearing in this issue, under the title: *Notice of the Zoological Writings of the Late C. S. Rafinesque.* A year earlier in the same Journal (vol. 40, No. 2, New Haven, 1841) the botanist Asa Gray published his famous: *Notice of the Botanical Writings of the Late C. S. Rafinesque.* Dr. Henry A. Pilsbry, in conversation with the writer at the Academy of Natural Sciences, in Philadelphia: October, 1943, said—"S. S. Haldeman, the zoologist, acquired Rafinesque's papers, drawings and specimens on zoology, botany, shells, and fishes; that he kept the material on zoology; and presented to the Academy of Natural Sciences at Philadelphia the Rafinesque material on botany and shells, under the presentation notice: 'Original Mss. of Rafinesque presented to the Academy by S. S. Haldeman, Nov. 13, 1849.' The papers on fishes, but not the specimens relating thereto, Haldeman gave to the United States National Museum, Washington." The placement of other items acquired by men of science is a matter of record, and occasionally even now after one hundred years additional placements are discovered. For example: The archives of the Chester County Historical Society, West

Chester, Pennsylvania, contain a letter written by Peter A. Browne, professor of geology and mineralogy at Lafayette college, Easton, Pennsylvania, and a corresponding member of the Chester County Cabinet of Natural Science (life of this organization—from 1826 to 1850). The letter, dated from Philadelphia, September 26, 1841, reads thus: "To the Cabinet of Natural Science of West Chester, Gentlemen: I beg your acceptance of the accompanying two small MS. volumes of the late Professor C. S. Rafinesque. I am —— (signed) P. A. Browne." So varied were the research activities and so voluminous the writings of this unpredictable genius Rafinesque, there is no telling where material of his may be turned up in the future out of the saved remnants of his vast production.

Brantz Mayer (1809-1879) the son of German immigrants, was educated and prepared for the legal profession in Baltimore and at adjacent Maryland schools. In the year 1841 he was appointed secretary of the American Legation in Mexico City, and spent one year (from November 1841 to November 1842) in Mexico. While there he developed a great interest in Mexican history and archaeology. Returning to the United States, he landed at New Orleans, December 1842; and immediately upon reestablishing himself in Baltimore, began a long series of writings on Mexican history and prehistory which were continued throughout the rest of his life. Incidental to our subject, he wrote a most interesting and authoritative history of Mexico which had a wide distribution in the United States and in Europe because of its timely appearance just before the outbreak of our Mexican War. One of Mayer's prime objectives which he set for himself at this time was the organization of a historical society in the State of Maryland. Gathering together a group of interested associates he developed the idea until in January 1844 a called meeting held in Baltimore set in motion the preliminary organization of the Maryland Historical Society. April 5 of the same year a permanent organization was effected. Mayer was elected the Society's secretary, which position he held until elevated to its presidency after the death of General Smith, the Society's first president, in the year 1867.

In *Niles' National Register* (Baltimore, vol. 67, No. 20, page 312) for January 18, 1845, appeared the following: "*Maryland Historical Society:* The regular monthly meeting of the Society was held at the historical rooms, on Thursday evening, Dec. 5th, (1844.) - - - - - From Brantz Mayer, esq., was received - - - - - also pieces of birch bark with picture writing and hieroglyphics by northwestern Indians, and other curiosities." Throughout the eastern States in the 1840's "northwestern Indians" meant Indians in the old Northwest Territory. Whether or not those "pieces of birch bark with picture writing and hieroglyphics" were Walam Olum pictographs probably one will ever know. A visit to the Society disclosed no description of the gift, and only the knowledge that it was removed from the archives by the donor. On the Society's Gift Book opposite the recording of the gift is the following pencil notation: "Withdrawn by him, September 29, 1875. B. M."

In addition to his active interest in history and archaeology, Mayer developed a kindred interest, the collection of rare Americana, as sub-

sequent incidents proved. Certain it is that he acquired the Walam Olum some time during the decade of the 1840's, but under what circumstance and from whom is still a mystery. June 1847, the Smithsonian Institution accepted for publication the now famous volume of E. G. Squier and E. H. Davis: *Ancient Monuments of the Mississippi Valley*, published the following year—1848. On page XXXVI the following is quoted from the authors: "Several plans and notices - - - - - are presented in the succeeding chapters, upon the authority of the late Prof. C. S. Rafinesque. This gentleman, while living, devoted considerable attention to the antiquities of the Mississippi valley. - - - - - His notes and plans - - - - - at his death found their way into the possession of Brantz Mayer, Esq., of Baltimore, late Secretary of the American Legation to Mexico. This gentleman placed them in the hands of the authors, with liberty to make use of the information they contained." The authors did not mention the Walam Olum in their volume, but that this manuscript was included in the material loaned to them, to be more correct loaned by Mayer direct to Squier, is attested as follows. Squier, in the same year *Ancient Monuments of the Mississippi Valley* came off the press (1848), read a paper on Rafinesque and the Walam Olum Record before the New York Historical Society. A copy of this rare pamphlet autographed by the author is in the archaeological library of the Indiana Historical Society. Squier's paper was reprinted in the *American Whig Review*, New York, February, 1849; and later in the *Indian Miscellany*, edited by W. W. Beach, (Albany, 1877). April 11, 1851, Mayer wrote to Spencer F. Baird, secretary of the Smithsonian Institution, as follows, extract quoted: "I shall now write to Mr. Squier for the Rafinesque papers." (Bureau of American Ethnology, William N. Fenton, letter January 27, 1944: *In* S. F. B. Letters Received, Book 1.)

After 1851 the subsequent history of the Walam Olum lies shrouded in mystery until the suggestion of its reappearance, forecasting the history of January, 1876, comes to light in the withdrawal of the Indian "hieroglyphics" from the Maryland Historical Society, September 29, 1875. Meanwhile, in the year 1870, Bangs, Merwin and Company, 694 and 696 Broadway, New York City, N.Y., issued a "*Catalogue of a Choice Collection of Books*, in various departments of literature, including the entire library belonging to Col. Brantz Mayer, of Baltimore, Md., comprising an extensive and valuable series of books relating to the History of Maryland, Mexico, Central America, etc., etc., Also, a Large and Unique Series of Tracts relating to Maryland and the Southern Rebellion, Works relating to the Indians, Indian Narratives, etc. . . . N.B. A large number of Mr. Mayer's Books are Illustrated with Autograph Letters." This collection was advertised for sale at auction on Monday, September 26, and five days following, the year 1870. A copy of this catalogue has been presented by Mr. Jacob Blanck, New York City, N.Y., to the archaeological library of the Indiana Historical Society—a volume of 180 pages containing a list of 2,452 items, the first 1,612 of which were from the Mayer library. *Rafinesque items are not listed.* This sale was evidently arranged the year before Mayer went to California in 1871 for a visit combining legal work for eastern clients and a vaca-

tion. He had arranged his affairs in Baltimore, including his resignation as president of the Maryland Historical Society. What may have been his ideas at this time concerning the value of the Rafinesque papers as either scientific papers, historical documents, items of Americana, or a combination of these, no one knows. Whatever may have been the conditions, the Walam Olum was still in his possession January 30, 1876. In the summer of 1875 he had returned from California to Baltimore: As he wrote to his friend, John A. McAllister, of Philadelphia, in a letter from Baltimore dated March 3, 1876: extract quoted: "Last summer [I] came back to Baltimore to pass the rest of my days." (Ms: Brantz Mayer letters: the Library Company of Philadelphia.) It was in September of this year that he removed from the Historical Society's collections the Indian pictographs (so-called "hieroglyphics"), which he had presented to the Society thirty-one years before. The following January 30, 1876, he bound in a brown manila paper wrapper his Rafinesque material. The outside cover bears his name and address, to wit: "Brantz Mayer, Esq., Maryland Hist. Society, Baltimore, Maryland." On the reverse inside cover in his handwriting in black ink, he wrote the following:

"Memorandum: The enclosed original papers in the Manuscript of Mr. Rafinesque were given to me some thirty years ago— (loaned by me to Squier when writing his ANTIQUITIES with Davis—) and contain the first real antiquarian researches in the U. States, properly undertaken. Brantz Mayer, Sunday, January -30- 1876." Below the signature and date he wrote—"Rafinesque papers American Antiquities Ancient geography and his Olum Wolum."

After his return to Baltimore in 1875, Mayer must have continued his collecting of bibliographic Americana, because a few months after his death at Baltimore in 1879, Sullivan Bros. and Libbie, of Boston, offered for sale by auction on November 11-12-13 of that year some six hundred listings containing thirteen hundred items of Mayer's personal and collected manuscripts, books, drawings and related materials. A copy of this catalogue is in the collections of the Maryland Historical Society, Baltimore. *No Rafinesque items are listed in this catalogue.* At least a partial assembly of the purchasers from this sale was discovered. Inquiries to them as to whether Rafinesque items came into their possession from this sale drew only negative replies.

Daniel G. Brinton had no knowledge of the whereabouts of the Walam Olum manuscript in 1883. In his *Aboriginal American Authors* (Philadelphia, 1883) he discusses the Walam Olum at some length, and characterizes it as one of the most curious examples of aboriginal American authorship: a short account of the early history of the Delaware tribe, "written in that idiom, with mnemonic symbols attached." He essays a short history of the Rafinesque document, tracing it finally into the possession of E. G. Squier. He concludes his notice with the statement (page 2, N.B.)—"I have not been able to find the original." Two years later when his *Lenape and Their Legends*, which contained his great treatise on Rafinesque's Walam Olum, was published (Philadelphia, 1885) the work had been done from the original Rafinesque manuscript. It is evident that in 1883 he had no knowledge of Mayer's

connection with the material, which is quite strange in view of the Squier and Davis statement in their *Ancient Monuments of the Mississippi Valley*. However the case may have been, shortly after his 1883 publication it is evident that some person was able to inform Brinton of the then present ownership of the document. The only statement so far discovered in this connection is in Brinton's monograph *Record of Study in Aboriginal American Languages* (printed for private distribution, Media, Pennsylvania, 1898: page 12)—"The beliefs and customs of the Delawares of the present day . . . I collected in the article *Lenape Conversations* (American Journal of Folk-Lore, vol. 1, 1888.) A few years previous I had succeeded in obtaining the singular MS. referred to by C. S. Rafinesque in 1836 (in his *American Nations*, Philadelphia, 1836), as the 'Painted Record of the Delaware Indians, the Walam Olum'." A copy of this very rare pamphlet has been presented to the Indiana Historical Society by Dr. J. Alden Mason, of Philadelphia, on behalf of the University Museum and the Philadelphia Archaeological Society, co-trustees of the Brinton scientific and archaeological printed literature housed in the Brinton Memorial Library at the University Museum.

In conclusion, and summarizing our material, the Walam Olum passed from its Delaware Indian keepers through the mysterious Dr. Ward to Rafinesque. At his death it was rescued from oblivion by an unknown "man of science," and shortly thereafter (between 1840 and 1846) came into the possession of Brantz Mayer, who kept it "some thirty years." After Mayer's death in 1879 the manuscript through some channel or channels was acquired by Brinton (between 1883 and 1884 or 1885). By him it was presented to the University Museum, Philadelphia, where it is now stored in the archives. There is no knowledge to confirm the possibility of authenticating the mnemonic pictographs referred to as Walam Olum pictures. However the coincidence of their history, slight as it may be, paralleling the history of the manuscript vouches for the necessity of this inclusion.

In so far as his fine discriminating scholarship permitted him to judge, Brinton affirmed the authenticity of the Walam Olum document as a transcription, possibly in abbreviated form, of the ancient Lenape (Delaware) Indian story of creation, their deluge version, and subsequent history, originally and for many generations passed down by word of mouth with the aid of memory stimulating pictorial mnemonic symbols accumulated through the generations in the substance of a bundle or bundles of either bark or stick tally records.

Botanical Survey of the Angel Mounds Site

HELEN MARSH ZEINER, Lincoln, Nebraska

The study, a preliminary report of which appeared in volume 51 of the *Proceedings of the Indiana Academy of Science*, resolved itself into two parts: a general taxonomic survey of the vascular plants of the region, and a detailed ecological study of the site of the old village wall.

I. General Taxonomic Survey.

The general taxonomic survey was begun early in the spring of 1941, and carried through the growing season of 1942. During the two seasons, 339 different species of vascular plants were collected and identified. Five additional species were identified to the genus only. Of the 339 species, 241 were new records for Vanderburgh county, and one a new record for Warrick county. Most of the plants were very common, reflecting the fact that Vanderburgh county has been neglected by plant collectors, but a few rare plants were found and previously reported (Proc. Indiana Acad. Sci., 51:68, 1941). Many of the plants growing at the site were important in the economic botany of various Indian tribes, and it seems reasonable to suppose that they were used by the inhabitants of the site.

II. Study of the Wall Site.

The site of the wall was marked by a variation in plants which formed a strip extending across the fields. In an effort to discover an explanation for these differences, six transects ten feet wide and about 100 feet long were staked off across the wall site, and studied in detail over a two-year period with respect to plant distribution, pH of soil, soil nutrients, and elevation. At the end of the study, sections of two test areas were excavated.

A correlation between plant distribution, pH, and elevation was confirmed in all cases. During a two-year period, pH readings taken at different times of year, at different depths, and at different frequencies across the transects always gave similar curves, with a distinct drop in pH at the spot where the elevation and plant differences were greatest. Tests for potassium, phosphorous, and nitrates showed no corresponding curve. Plant distribution was carefully charted for the two growing seasons, and the results were always the same. When the pH falls to 5.00 or below, *Aster pilosus* is stunted in growth or absent, depending upon the degree of acidity. *Plantago lanceolata* is also intolerant of the more acid regions. *Plantago aristata, Rumex acetosella,* and *Danthonia spicata,* on the other hand, grow well with the pH below 5.00, and are not tolerant of the more alkaline soils.

Elevation readings, although the difference was often less than a foot, in each case showed the greatest elevation at the point of greatest acidity and greatest difference in plant growth.

A section parallel to a test transect was limed the second season with five pounds of air-slaked lime to each ten-foot block, resulting in accel-

erated growth of plants on the wall site, particularly marked in the case of a few plants of *Aster pilosus* growing there.

At the end of the second year, Mr. Glenn Black supervised the excavation of portions of two transects, and showed the center of the palisade trench to be where it was predicted on the basis of the above data; that is, where the elevation was greatest, pH lowest, and plant differences most striking.

Although the study strongly indicates that the peculiar plant distributions were due to acidity differences, it is not to be presumed that this was the sole cause. It is possible that toxic minerals were present, but the increased vigor of plants on the limed area suggests that if such substances were present, they were not as important as acidity in affecting the growth of the plants.

Dryness of soil on the wall site appears to be due to absence of plants and not the reverse. This conclusion is reached on comparison with artificially denuded areas. Growth of plants on artificially denuded areas emphasizes the peculiarity of growth on and along the site of the wall. In these other areas, either plants similar to the surrounding growth or rank weeds common to the area quickly make their appearance. If it were a question of soil moisture alone, we should get the same effect on the wall as on other bare areas. The results of liming also point away from soil moisture and towards acidity as the cause of plant differences. Also seedlings do not appear on the wall site even when the soil is moist in the spring.

It seems apparent that the wall must have been responsible for creating soil differences which exist to this day. Just how this was accomplished is open to conjecture. There is no doubt that we are faced with a problem of peculiar deposition. Over a period of years soil was washed down from the mud-plastered wall by rains, and so a deposit of clay with lime salts washed out of it was built up. The logs of which the wall was built probably decayed under conditions of poor aeration, and decay of organic materials under such conditions is a cause of soil acidity.

At present there seems to be no way to determine which of the possible explanations for the soil acidity, if any, is the correct one, or whether they were all contributing factors. They are set forth as thought-provoking possibilities, and are not intended as conclusive evidence of what may have happened.

BACTERIOLOGY

Chairman: LYLE A. WEED, Indiana University Medical Center

The BACTERIOLOGY SECTION met with the Indiana Branch, SOCIETY OF AMERICAN BACTERIOLOGISTS.

Dr. C. M. Palmer, Butler University, was elected chairman of the section for 1945.

The nature of "nibbled" colonies of bacteria resistant to bacterial viruses. S. E. LURIA, Indiana University. After the action of a bacterial virus (Bacteriophage) on a sensitive host, among the secondary colonies of resistant bacteria there often appear "nibbled" colonies. They are distinguished by irregular shape and texture, and are often reduced to thin, barely visible residues. Bacteria isolated from such colonies usually prove as resistant to the virus as the bacteria from regular secondary colonies.

We discovered recently the occurrence of virus mutants capable of attacking bacteria resistant to the normal viruses. It seemed possible that the nibbled colonies might result from the lytic action of some mutant virus particles on secondary colonies resistant to the normal virus. If so, then nibbled colonies should also be obtainable by plating a few cells of a pure resistant bacterial strain with a virus mutant active upon it. Experiments with several strains of resistant bacteria and of virus mutants fully confirmed this expectation. By plating together various amounts of bacteria and of virus, it was possible to duplicate all types of nibbled colonies (slightly nibbled, largely nibbled, thin), as appear in secondary growth after lysis of sensitive bacteria by normal viruses. Whenever nibbled colonies had been found in the resistant growth, it was possible to isolate from the virus at least one mutant active on the bacteria of the secondary growth. Several new mutant viruses were thus isolated from different coli-virus strains.

Interference between particles of closely related bacterial viruses. S. E. LURIA, Indiana University. Interference between different viruses has been described for many viruses, including bacterial viruses (Bacteriophages). Interference is also supposed to occur between particles of the same virus (self-interference), and, in plants and animals, is considered as being partly responsible for acquired immunity.

For bacterial viruses, occurrence of self-interference has been inferred indirectly. Direct proof is difficult to obtain, because particles of the same virus are indistinguishable and one cannot follow the growth of a certain virus particle in a culture. Our recent isolation of mutant bacterial viruses, indistinguishable from the normal viruses when acting on a common host but active on a new host resistant to the normal viruses, permitted a further study of self-interference. The mutant virus, while identical with normal virus in its action on the common host, is traceable through its activity on the new host.

Cells of *Escherichia coli* strain B, susceptible to virus γ and virus γ^1 (mutant), were infected with virus γ, and immediately after with virus γ^1. Then, before lysis took place, the infected bacteria were plated with strain $B\gamma$, sensitive to virus γ^1 only. Those bacteria that liberate γ^1-particles should produce plaques. It was found that almost all the bacteria infected first with virus γ, then with virus γ^1, failed to liberate any virus γ^1. Since we know that viruses γ and γ^1 are indistinguishable in their action on strain B, these experiments prove the occurrence of interference between virus particles acting in the same way on the same host-cell.

A study of non-toxic strains of Clostridium tetani. RUTH TOABE and L. S. MCCLUNG, Indiana University. At the request of Dr. J. H. Mueller, from whom the culture was received, a study has been made of a strain of *Clostridium tetani* which lost the property of toxin production following a period of serial daily transfers in meat infusion glucose broth. In addition, 10 other non-toxic and 33 toxic strain mostly received from Janet Gunnison have been included in our series. The 10 strains are presumed to have been non-toxic on original isolation but possess other characters, including agglutinating antigens which are normal for the species. All strains have been studied with respect to the following: cell morphology, spore formation, motility, extensin physiological reactions and colony type.

To date, no significant difference has been observed with respect to the above mentioned characters, in the various strains except that in the serial passage culture spore formation is markedly retarded. This is not true of the original culture from which this strain was derived. Rough-smooth dissociation apparently has not occurred. An attempt to repeat the phemenon of loss of toxicity by serial passage in thioglycollate broth and other studies on this and additional strains are in progress.

Antibacterial substances from plants collected in Indiana. DOROTHY SANDERS, PAUL W. WEATHERWAX and L. S. MCCLUNG, Indiana University. Following the suggestion by Osborn and others that antibacterial substances may occur naturally in plants, a preliminary survey has been made of the occurrence of such substances in a series of plants collected in Indiana during the summer of 1944. In general the juice of the plants, or particular portions of them, obtained by a Carver hydraulic press, was tested for inhibitary activity against *Bacillus subtilis* and *Escherichia coli* using the Oxford cup technique. Representatives (1 to 50 species) of the following families have been included: Plantaginaceae, Ranunculaceae, Gramineae, Araceae, Solanaceae, Papayaceae, Phytolaccaceae, Polygonaceae, Lilicaceae, Compositae, Asclepiadaceae, Violaceae, Menispermaceae, Labiatae, Euphorbiaceae, Caprifoliaceae, Saxifragaceae, Oxalidaceae, Iridaceae, Onagraceae, Leguminosae, Umbelliferae, Anacardiaceae, Ulmaceae, Apocynaceae, Rosaceae, Solanaceae, Aceraceae, Celastraceae, Alismaceae, Anonaceae, Magnoliaceae, Nymphaeaceae, Juglandaceae, Tiliaceae, Vitaceae, Ericaceae, Polypodiaceae, Osmundaceae, Acanthaceae, Celastraceae, Convolvulaceae, Primulaceae, Urticaceae, Typhaceae, Scrophulariaceae, Balsaminaceae, Simarubiaceae, Lauraceae,

Bignoniaceae, Rubiaceae, and Martyniaceae. Although about 15 of approximately 150 specimens tested show some degree of inhibitory activity against one or both test organisms, no sample has been encountered which gave exceptionally high values. Perhaps the greatest activity was shown by extracts of the common ragweed, *Ambrosia elatior*, though this was not true of the giant ragweed, *Ambrosia trifida*. It should be mentioned that in many instances a very marked stimulation of growth of the test organisms was evident.

Pathogenesis, Diagnosis and Treatment of Clostridium Welchii Infection

LYLE A. WEED, Indiana University Medical Center

In recent years considerable work has been done on the toxins of the various strains of *Cl. welchii* and the relation of these to pathological processes. In spite of this the treatment of clinical cases considered to be due to invasion by this organism is entirely unsatisfactory and there is no uniform agreement as to what constitutes a proper therapeutic program. It is proposed here to present certain considerations relative to pathogenesis and diagnosis which may stimulate a discussion to throw some light on the problem of treatment. No claim is made that a new theory is postulated concerning the modus operandi of such infection and no satisfactory method of treatment is presented. Rather, it is desired only to present certain facts which have recently been overlooked, or at least not given important consideration, with the view of stimulating inquiries along lines of endeavor which may lead to the development of a satisfactory treatment.

Pathogenesis

In 1892 Welch (46) described an organism which probably was identical with the one commonly bearing his name. The organism was isolated at autopsy eight hours after death from the blood of a patient who had died from tuberculosis and a syphilitic aneurysm. The original description was incomplete as far as present day bacteriology is concerned but many of the features of the organism indicate with a fair degree of certainty it was what would today be called Cl. welchii. It is to be noted that the organism was isolated from the blood after death and there was nothing in the clinical history to indicate it was related to the cause of death, directly or indirectly. Because of the lack of development of satisfactory bacteriological procedures, especially as regards anaerobes, Welch devised the following procedure as one for rapidly identifying the organism. A suspension of the culture in question was injected intravenously into a rabbit and the animal killed after circulation had fully distributed the organisms throughout the body. The carcass was then incubated overnight and the ballooned body was interpreted as indicating the presence of Cl. welchii. This mechanism is due to the formation of gas much as it is formed in milk where the reaction is called "stormy fermentation."

In the course of the next few years many reports appeared in the literature concerning the nature of the organism, its distribution in nature and its relationship to certain disease processes, especially to infections in and around wounds of the extremities. The procedures used by many of these authors were entirely inadequate to enable one to say definitely whether the organisms they were studying were identical with the Welch bacillus but there nevertheless gradually developed the idea

that certain types of tissue changes around wounds were associated with such organisms and it soon became generally accepted as a fact that the organism was the *cause* of the tissue changes. This concept was not without foundation for it was shown that injections of animals with pure cultures of the organism produced swelling of the extremity, with interstitial gas and edema rather suggestive of clinical gas gangrene. Since the organisms were found widely distributed in nature (including soil, sewage, water, fish, milk, cheese, a great variety of foods, various types of cartridges, feces and tissues of animals, skin of humans, mouths of infants, human salivary glands and their ducts, normal human bile, normal appendices and meconium of infants) (38), it was easy to understand how the infection would result from direct contamination of open wounds, particularly deep wounds with ragged margins and under such circumstances that the inoculum would likely be enormous. However, the condition of gas gangrene is rarely the site of a pure culture of the anaerobe but nearly always contains mixtures of organisms and this makes it difficult, if not impossible, to properly evaluate the relative importance of the various bacteria as possibly contributing to the infectious process. However, since experiments had shown pure cultures of the organism would produce fatal infections on the experimental animal (47), it soon became the procedure to look specifically for this organism in certain infections and to give little or no consideration to the associated bacterial flora.

During the first world war when better bacteriological procedures were available, data were collected by the military forces relative to the types of organisms present in various wounds and the incidence of gas gangrene. The data (3, 12, 19, 28, 36, 37, 39, 40, 41, 45, 48) show very clearly that rarely is there only one type of organism present. In fact, aerobes were so comonly present in cases of gas gangrene that various investigators have considered the process to be one of symbiosis. The line of reasoning in support of this is somewhat as follows: The aerobes proliferate and thereby use up sufficient oxygen to establish a satisfactory reduction potential to allow development of the anaerobes. The latter then liberate injurious agents which are absorbed by the blood circulation to produce the local and general reactions observed in patients.

It should be remembered, however, that by definition symbiosis requires a mutual benefit to the organisms resulting from the biologic action and there is no indication in the above philosophy that the aerobes are benefitted in any way by the growth of the anaerobes. Therefore, if there be any truth in the mechanism postulated, the above outlined mechanism should more properly be considered as synergism rather than symbiosis. On the other hand, there is little or no evidence to indicate such synergistic action takes place in the clinical case and we have been unable to obtain evidence in the experimental animal to support this philosophy. We have incoulated mice, hamsters and guinea pigs with mixtures of *Cl. welchii* and various aerobes commonly found in wounds and have not been able to enhance the disease of gas gangrene by the addition of such aerobes. It is entirely possible however, that a proper strain endowed with special qualities on the part of the aerobe are

necessary for proper synergistic action and that it is purely a matter of chance that the proper combination is rarely obtained.

Another feature of wound infection which is commonly overlooked is that *Cl. welchii* capable of producing a true toxin are many times present in traumatic wounds and clinical symptoms of gas gangrene never develop (6, 7, 11, 24, 42). This could be easily explained on the grounds that such conditions represent antitoxin immunity on the part of the patient. There is little or no information in the literature to support such an hypothesis and the experiments dealing with naturally occurring *Cl. welchii* antitoxin in humans do not indicate that the level would likely be significantly high. Sir Almroth Wright in his investigations of wound healing during the first world war concluded that such resistance to infection was due to the substance which he called antitrypsin and that when *Cl. welchii* grew in a wound it reduced the antitryptic power of the tissue and elaborated acid (49). Wright also offered data supporting the view shared by other workers of the time that the presence of a foreign body was extremely important in the production of clinical symptoms. The exact mechanism of such bodies is rather vague but the interpretation revolves around the idea they serve as nidi to support growth. During growth the organisms liberate a variety of substances which tend to destroy more tissue which serves as a substratum for further growth. One factor which is known to enhance the development of gas gangrene is the presence of relatively large amounts of calcium ions (2, 5, 13, 14, 16, 27, 28, 30, 34). It was found from analyses of soil from various battle fronts in Europe during the first world war that the increased amount of calcium in certain areas probably accounted for the greater incidence and severity of infection in wounds received in those areas. In the experimental animal it has been repeatedly demonstrated that fewer organisms are necessary to initiate an infection when calcium ions are simultaneously inject than when organisms are injected alone.

Some of the products of growth of *Cl. welchii* many times may produce changes which indirectly accelerate the infection once it is started. In an extremity, for instance, the gas produced may be so great as to completely cut off the blood supply by compressing the artery. In the earlier stages the tissues may be so swollen as to produce serious interference with venous return and thereby materially handicap the normal metabolic changes which are necessary for the natural immunity, whatever is included in this concept. It might be the presence of some specific growth inhibitor or the absence of some nutritional substance necessary to stimulate bacterial multiplication but which substance develops as a result of poor circulation. Wright was of the opinion that the acid produced was picked up by the circulation and thereby caused a decrease in the antitryptic power of the serum. The acidity of the blood, as he measured it, however, became evident only late in the disease and could hardly account for the pathogenesis. In some of our preliminary experiments, by measuring the CO_2 combining power in place of titrating with alkali as Wright did, we have not been able to demonstrate a significant change in the acidity. The type of acid produced in tissues has not been

determined but in the test tube there is evidence that at least in some cases it is butyric. Some authors have even gone so far as to claim that butyric acid was the cause of death in this type of infection but our own experiments have not supported this point of view (43).

Other substances which are known to be produced by *Cl. welchii* in the test tube include many toxic agents and true exotoxins in the sense that they are poisonous, produce specific reactions and stimulate the production of specific neutralizing substances called antitoxins. During the early days of the first world war many investigators pointed out the symptoms of intoxication in human cases and in experimental animals but it remained for Bull and Pritchett (4) to demonstrate a poisonous filterable substance which could be specifically neutralized by an antitoxin. It should be pointed out, however, that the demonstration of antitoxin was from the standpoint of *protecting* guinea pigs and pigeons against a lethal infection and that their experiments relative to treatment during well advanced infections leave much to be desired. Since then most of the research concerning infection with *Cl. welchii* has been done on the toxins, a complete review of which has been given by Oakley (35). In spite of all the work which has been done on the toxins and the demonstration that certain of them will kill the experimental animals, two facts remain dominant: one is that the syndrome of clinical gas gangrene is not entirely reproduced by such materials and the other is that antitoxin therapy is still entirely inadequate in both the human and the experimental animal once the infection is well established (2, 13, 14, 16, 27, 28, 30, 34). It is theoretically possible that in an actual infection some different toxin is produced from that obtained by growing the organism in the test tube and that antitoxin therapy is on the wrong basis. It may be that the toxin produces an irreversible cardiac or cerebral damage, so that circulation eventually fails, even though the toxin is neutralized. Many of our experiments support this point of view (unpublished data).

We come now to a consideration of clinical gas gangrene as encountered in the human under natural conditions and in the experimental animal under artificial but controlled conditions. In either case a severe and fatal infection will give rise to many or most of the following conditions. Early in the course of the disease there is considerable pain. This is uniformly true in dogs, guinea pigs and mice, as well as humans. This appears to progress with the swelling which begins in the animals in one to three hours, depending on the dosage. As soon as swelling is definite, there usually develops a pitting edema which progresses rapidly, indicating some damage to the regional capillaries. In a short time (3-5 hours from time of infection in the experimental animal) the edema will be so extenesive as to produce a discoloration of the skin ranging from bright red to reddish-brown and later becoming bluish-red as indicative of definite necrosis. Concurrently with the onset of edema, the pulse accelerates, the blood pressure soon becomes lowered, the red and white count increase proportionately leading to the symptoms of shock as if resulting from hemorrhage or a burn. The animal loses interest in the surroundings, the respiration becomes rapid and shallow, the beast lies stretched out on the side and the conditions progress until death in-

tervenes at which time the animal gives a series of deep gasps as if being unable to keep up adequate circulation and aeration. At autopsy there is no significant involvement of the lung and the right heart is engorged. In the case of death within a few hours from the time of infection, there are seldom any demonstrable gross changes in the remaining viscera. At the site of infection there is extensive edema with a serosanguinous, gelatinous material which may extend in the subcutaneous tissue, far up on to the abdomen and chest and even across to the opposite side. Sometimes there will be extensive infiltration of such material into the abdominal cavity per se. If the infection is in the thigh and the weight of edematous tissue be compared with the normal tissue of the contralateral side it will be found that there has been much loss of fluid from the circulation as would be expected from the Hb. and R.B.C. determination. Considering that the symptoms of shock should be treated as such, we have given animals large doses of dog plasma and serum but without any satisfactory therapeutic results. Other animals we have treated with antitoxin after the disease is well developed and obtained only very irregular results; sometimes the animals survived a few days and died with mixed septicemia and other animals with larger doses of antitoxin died as if they had been untreated. Whether treated or untreated, many human and animal infections develop hematuria, hemaglobinuria and even jaundice. Whereas it is generally considered that dog tissues (esp. muscle and liver) contain many other organisms that are not toxin producers, we have been able to establish monovalent infections with *Cl. welchii* by injecting the thigh muscles through an area of skin cauterized by heat after infiltrating the overlying skin area with cocaine. It is known (35) that the so-called alpha toxin will produce hematuria in mice. In the human, hematuria and jaundice have occasionally been recognized but not as constant features and, of course, such conditions may conceivably be reflections of mixed infections.

It should be emphasized that in the human the clinical condition may progress rapidly and the patient be in extremis in a few hours only to recover spontaneously with only surgical treatment and sometimes not even that (6, 7, 11, 24, 26, 42). On the other hand symptoms may be relatively mild and the patient die in a few hours without developing recognizable general symptoms (1, 6, 7, 11, 17, 24, 42).

Diagnosis

In order properly to evaluate the clinical material relative to various therapeutic agents, it is desirable to review the various features commonly used to establish a diagnosis. In most cases the presence of swelling of a wound, especially if it develops rapidly and is associated with a pitting edema and crepitation, is considered sufficient by most physicians to suspect gas gangrene. These features, however, may be the result of activity of many bacteria and do not necessarily incriminate any anaerobe. It has been demonstrated (10) that many common aerobes may give rise to similar local reactions. X-ray examination is commonly used to determine the extent and progress of development of gas in the

tissue but this may be misleading in that many times little or no demonstrable gas is present or there may be so much air in the tissue one can not radiographically definitely demonstrate any small increase with progress of the disease. If one suspects the possibility of gas gangrene with an anaerobe as the causative agent, it is customary to ask the bacteriologist to demonstrate *Cl. welchii* or similar organism rather than to attempt a complete bacteriological evaluation of the condition. For such information it is a common procedure to inoculate boiled milk and look for stormy fermentation which will many times be interpreted as prima facia evidence of "gas gangrene *due to Cl. welchii.*" In those cases reported in the literature where careful bacteriological work has been done, it is evident that monovalent infections due to *Cl. welchii* alone are very uncommon.

For this reason it is a question whether cases of gas gangrene reported as due to *Cl. welchii* actually represent simple infections. It is therefore logical to suspect that the treatment of the condition with any agent is likely to result in failure or at least be unsatisfactory unless due consideration is given to the effect of the associated organisms. In most cases this is not done. On the other hand, the aerobes commonly present in wounds the site of gas gangrene are staphylococci and/or streptococci, most of which respond well to treatment with sulfonamides or penicillin. These products are used extensively in the various war theaters in addition to antitoxin without greatly reducing the mortality rate. This suggests the clinical symptoms may not be due entirely to either the associated aerobes or the known toxins of the anaerobe but may be due to some other substance not produced in artificial culture medium.

Treatment

In order to indicate the need for further work on this problem it will be well to review briefly a few of the various procedures which have been advocated for the treatment of this condition.

Since the *Cl. welchii* is an anaerobe various oxidizing agents have been employed. These include hydrogen peroxide, potassium permanganate and more recently, zince peroxide. There is some experimental work indicating the latter might be valuable but the problem of having satisfactory zinc peroxide and the problem of obtaining adequate contact with the organisms finally makes the procedure unsatisfactory and the mass results are disappointing (8, 15, 20, 31). Sulfonamides of various types have been tried in the experimental animal with widely varying results but the entire data, pooled together, do not offer much encouragement although selected experiments have yielded brilliant results (9, 16, 21, 32). Tyrothricin is very toxic when administered subcutaneously or intravenously and the conditions in the wounds make it almost impossible to obtain satisfactory contact with the organism. Our own experiments are in accord withe this conclusion. Penicillin has been tried clinically and experimentally and the results in the available literature indicate it is not satisfactory (10, 22, 23, 29). The clinical cases reported where it has been used are rather too few to permit drawing sweeping con-

clusions as to its therapeutic value. X-ray has been used by many workers and its use widely advocated by Kelly and others (25, 33). However, the more recent experimental work as concerns the value of x-ray in the treatment of these infections does not support the earlier hopes which, in fact, had no experimental basis. If it should eventually be shown that x-ray is of statistical value in such treatment, then additional work will be necessary to determine the mechanism of such results because experiments have already clearly demonstrated that in maximum doses tolerated by humans, x-rays will not kill the organisms, retard their rate of growth, destroy the lethal, hemolytic or dermonecrotic toxin as tested in vitro or in vivo (44). The clinician is inclined to reassess the experimental data obtained on laboratory animals on the grounds that the human is an entirely different type of animal and the results are therefore not directly transferable to clinical cases. It is to be noted, however, that many of the experimental data have been obtained on dogs and the veterinarian is just as enthusiastic about the value of x-ray therapy of infections as the medical man and in his work, the experimental animal *is* the clinical case.

The therapeutic value of *Cl. welchii* antitoxin has been a puzzle since its early inception late in World War I, where it scarcely had opportunity to be properly evaluated. The limited data available on its use, however, were favorably interpreted and it was soon considered as a routine part of the surgeon's armamentarium for human cases. Around 1930 enough civilian cases of *Cl welchii* infection had been seen and treated in the routine fashion with such disappointing results that there was a real interest in the development of something more certain of saving life.

By the time the present war was well under way, it was fairly well agreed that antitoxin was not the real answer to treatment and the data available from the military sources confirm this view. It is evident therefore, that the problem is open to a more thorough study in order to develop a proper understanding of the disease process and thereby develop suitable methods of prophylaxis and therapy. It is true many cases appear to have been cured or prevented independently by sulfonamides, Zn_2O_2, penicillin, x-ray and antitoxin. But the results are very irregular and unreliable. In this disease, time is measured in hours and minutes when therapy is considered. Therefore, one cannot vacillate and change from one method to another, hoping to select the proper procedure for a given case. In addition to this, many cases which appear to be moribund, recover spontaneously and dramatically with no more treatment than surgery and sometimes this is withheld. It is therefore quite evident we do not as yet fully understand the mechanism of death in this disease and do not have satisfactory prophylactic or therapeutic procedures to cope with it.

I wish to thank Miss Mary Clark for her valuable technical assistance in carrying out many of the experiments connected with this work.

Table I. Symbiosis of *Cl. welchii* (SR12) and Aerobes in Hamsters

Vol. SR12	Broth Control	Aerobe		
		Strep. hemolyticus	*Staph. aureus*	*E. coli*
0.2 cc.	2/2	2/2	2/2	2/2
0.1	2/2	2/2	2/2	2/2
0.07	2/2	2/2	2/2	2/2
0.04	2/2	2/2	2/2	2/2
0.02	2/2	0/2	2/2	2/2
0.01	0/2	0/2	2/2	2/2
0.005	0/2	0/2	0/2	0/2
0.002	0/2	0/2	0/2	0/2
0.001	0/2	0/2	0/2	0/2

Fractions give ratio of dead to total number of animals used.

Table II. Symbiosis of *Cl. welchii* (Gerbig strain) with Aerobes in Mice

Dilution of welchii culture	Welch Control	Aerobe		
		Staph. aureus	*Strep. hemol.*	*E. coli*
1:2	3/4	0/4	1/4	1/4
1:5	0/4	1/4	0/4	0/4
1:10	1/4	1/4	0/4	0/4
1:50	0/4	0/4	0/4	0/4

Table III. Symbiosis of *Cl welchii* with Stock Aerobes in Rats

Dilution of welchii culture	Welch Control	Aerobe			
		Staph. aureus	*Strep. hemol.*	*E. coli*	*Proteus vulgaris*
1:1	3/4	0/4	1/4	1/4	2/4
1:2	1/4	1/4	0/4	0/4	0/4
1:5	0/4	0/4	0/4	0/4	0/4
1:10	0/4	0/4	0/4	0/4	0/4
1:50	0/4	0/4	0/4	0/4	0/4

Table IV. Physiological Reactions of Dogs to Infection with *Cl. welchii*

Dog No.	Weight Lbs.	Blood Pressure (mm. Hg.)		Pulse (per min.)		Respirations (per min.)		Hemoglobin (gm%)		Red Blood Count (millions/cu. mm.)		Increase in weight of infected leg (gms.)
		N	T	N	T	N	T	N	T	N	T	
45	31	115–120	63	50–95	195	25–30	47	12	17	6	9	1100
65	33	125–130	35–40	50–60	180	20	50	12.5	11	6.5	5	700
67	40	130–150	46	70–80	200	20–30	......	15.3	19	8	13	1100
70	45	120–150	too low to read	75–80	150–160	hot weather, panting	......	13.5	19	5.5	10.8	1200
71	47	170–180	too low to read	90–100		60	no record	14	19.5	7	13	1600

N—normal value before infecting the animal.
T—terminal values obtained near the time of death.

Table V. Treatment of Gas Gangrene with Plasma and Serum
Animals Treated with Dog Plasma

Dog No.	Weight (lbs.)	Treated with Dog Plasma: Hr. and min. after infection	cc. given	Results
68	38	6:50	225	Well developed symptoms
		7:35	200	
		27:00	150	
		46:30		Died
69	39	6:50	500	Well developed symptoms
		10:00		Died
72	55	5:15	400	At 7:55 and 9:15
		7:15	300	1 cc. 10% Ca Gluconate
		10:00	400	At 10:05 1 gm. $CaCl_2$ 10 cc. H_2O
		11:15	300	With $CaCl_2$ as above
		11:55		Died

Animals Treated with Dog Serum

Dog No.	Weight (lbs.)	Hr. and min. after infection	cc. given	Results
78	32	8:30	Untreated control	Died
79	32	2:30	350	At crisis—before first transfusion. Hb 18 gm.%
		5:00	350	RBC 9,700,000 After 1800 cc. serum
		7:30	400	Hb 15.1 gm. RBC 6,000,000 Normal Hb 18.5 gm.
		9:30	800	Normal RBC 8,500,000
		13:00		Dead

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On the Preparation of Purified Influenza Virus Vaccine

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In 1933 Smith, Andrewes and Laidlaw (1), by utilizing a technique in experimental animals previously found effective in canine distemper experiments, reported on the action of a filterable virus recovered from epidemic influenza patients in Great Britain. Although virus etiology of influenza had been dealt with previously by other investigators, the experiments of Smith, Andrewes and Laidlaw utilizing ferrets were so convincing and definite that great interest was at once awakened in this work. These British authors for the first time demonstrated that nasal washings from patients ill with epidemic influenza contained a virus which was pathogenic on intranasal inoculation of ferrets. These animals exhibited characteristic temperature responses and presented evidence of infection in the nasal sinuses and the lungs. Repeated animal passage from one ferret to another resulted in enhanced virulence of the newly discovered epidemic influenza virus for ferret lungs, and gradually a more pronounced pneumonia began to appear in virus passage animals.

Following these first clear-cut experiments dealing with the isolation of epidemic influenza virus and its transmission in ferrets, various immunological aspects of the virus were determined. It was found that an animal convalescing from virus influenza exhibited a strong degree of resistance against further infection during a period of several months. Also it was observed that blood serum recovered from convalescent animals brought about neutralization of fully virulent epidemic influenza virus.

The knowledge of influenza virus was soon broadened by demonstration that the virus is pathogenic for Swiss mice (2) and, still later, that it is able to infect chick embryo tissues (3), and also bring about hemagglutination of erythrocytes of different species of animals (4). These two latter methods of infection along with hemagglutinating action (see Table 1) soon expedited widespread study of new strains of influenza virus, and many laboratories in different parts of the world, including Great Britain, the United States, Russia and Australia, began to publish reports dealing with different properties of influenza virus as isolated in different places. Immunization experiments in mice, ferrets, and human beings dealing with different strains of the virus were reported, and in the course of these it became apparent that differences existed between different strains. In other words, types of epidemic influenza virus were established (5). At the present time these types include type A and type B strains (see Table 2). Viruses of each of these types produce specific infections, and there is practically no crossover immunity between the two types. Possibly further types are yet to be discovered; however, present efforts in connection with the specific prevention of influenza utilize only well known strains of types A and B virus.

Experience in the serology of influenza soon shows the utility of the hemagglutination test. This test is a useful indicator of both the lethal potency of freshly prepared virus for Swiss mice and action of such virus when made into vaccine. Also the degree of neutralization of the hemagglutinating properties of the virus by serum serves as a rapid indicator of potency of influenza antibody, and resistance of experimental animals and human beings.

Prophylactic Influenza Antiviral Serum

During the last three or four years, considerable work has been done on influenza antiviral serum (6). No doubt the initial meager results obtained with the early vaccines prompted the preparation of influenza antiviral serum of such nature that this might be used as an intranasal prophylactic in case influenza became iminent. As yet there apepars to be little controled evidence, except that from Russian laboratories, which is available for judging the efficacy of influenza antiviral serum. However, some recent evidence has appeared indicating utility of influenza virus vaccine prepared as described below.

Influenza Virus Preparation on a Large Scale

Usually ten-day incubated hen eggs are used for preparation of influenza virus in large quantities for making purified and concentrated vaccine. Actual inoculation of these eggs comprises first treating the shell with a suitable antiseptic. We paint an area on the large end of each egg with Tincture of "Merthiolate" (Sodium Ethyl Mercuri Thiosalicylate, Lilly). Following this, a puncture hole is made in this area of the egg over the air cell. Using an automatically filling hypodermic syringe connected with a reservoir of "seed" virus, 0.2 cc. injections are made into the embryonic fluids of the egg using for the inoculum type A virus diluted 1:10,000 to 1:50,000 or more and type B virus diluted 1:1,000 to 1:5,000 or more (see Fig. 2). The openings in the shell are then sealed with paraffin, and the eggs are reincubated for approximately 48 hours. At this time the eggs are removed from the incubator and treated with antiseptic, following which a portion of the shell covering the air cell is removed aseptically. At this point the membranes surrounding the embryo are ruptured under sterile precautions, and the larger blood vessels are broken to assure as much hemorrhage as possible. (In this way the red blood cells of the embryo suffice for adsorption and subsequent elution of virus.) The mixture of virus-containing embryonic fluids and blood is then harvested by means of suitable aspiration apparatus and slight negative pressure. This material when accumulated in one-pint amounts is rapidly chilled at 2° to 50° C. in a water bath, and allowed to stand at this temperature for two hours or longer. Under these conditions the virus brings about cold hemagglutination of the red corpuscles and is adsorbed on the corpuscles in this process. When this has taken place, low speed centrifugation is done, and the supernatant fluid while cold is removed aseptically and discarded. Usually by far the greater proportion of the virus has been adsorbed by the red blood corpuscles, and relatively little is lost in the supernatant fluid.

The sedimented red blood corpuscles containing adsorbed influenza virus are resuspended in fresh physiological salt solution, preferably in one-tenth the volume of the original embryonic fluid, and are then subjected to a temperature of 37° C. for three to four hours. When treated in this way the cells redisperse from their previous agglutinated condition, and the virus elutes from the cells into the saline. When this reaction is complete, low speed centrifugation is again done, and the supernatant fluid containing the major portion of the original virus is aspirated off the red blood cell sediment (see Table 3 for hemagglutinating potency).

Conversion of Influenza Virus Into Vaccine

This purified virus concentrated by adsorption and elution as described is accumulated in large volumes and is inactivated with formalin 1:2,000 at ice box temperature. "Merthiolate," previously found satisfactory by the present author (7) for this purpose, is added in a 1:40,000 concentration as a preservative, and type A and type B vaccine lots are pooled in equal quantities. Epidemic influenza vaccine prepared in this way is subjected to immunization tests in Swiss mice. In these tests two doses of 0.01 cc. of vaccine each diluted up to 1.0 cc. in volume and given intraperitoneally must immunize against 10,000 LD50 of type A virus, and two doses of 0.0001 cc. of vaccine similarly diluted must immunize against 1,000 LD50 of type B virus (see Table 4 for immunizing potency in mice). Both type A and type B challenge virus comprise mouse lung passage material diluted decimally and given intranasally. The smaller challenge dose of type B virus is made necessary by the lower virulence of this virus; however, this is compensated for through immunization with much smaller doses of vaccine. The usual safety and sterility tests prescribed by the National Institute of Health finally are conducted, and upon release by the Institute the vaccine is ready for dispensing.

Responses to Epidemic Influenza Virus and Vaccine

In the course of earlier experiments with influenza virus and vaccine in ferrets, Swiss mice, and human beings, it was observed that various kinds of specific responses were produced against these agents. Serological studies of both animal and human blood before and after infiuenza and before and after use of influenza virus vaccine have shown marked differences in complement fixing titer, virus neutralizing titer, and protective antibody titer. Thus far, however, it has been impossible to utilize any definite titer of any particular antibody (i.e., comparable to the Schick test level of antitoxin in diphtheria immunity) to define a state of immunity against actual influenzal disease. In general, however, the lower antibody titers are associated with susceptibility, while the higher antibody titers are associated with resistance. The rather regular increase in antibody content during the course of infection has in fact some diagnostic significance in proving or disproving influenza, especially in view of the difficulties of diagnosing influenza by clinical grounds

alone. In other words, if serum drawn in the acute stage of an influenza-like condition is compared with serum drawn in early convalescence and the "convalescent" serum is found to contain from four to eight or more times as potent antibodies as the "acute" serum, the specific diagnosis may be made more certain.

Immunity Against the Disease

In view of the foregoing facts concerning the serology and immunology of influenza virus, it is finally necessary to observe the practical results obtained in human beings by use of influenza virus vaccine, in order to judge efficacy of this biological. During the widespread but rather mild epidemic of influenza in November and December, 1943, it was possible to do this in a limited way, and a military commission has reported favorable results in approximately 12,000 subjects comprising certain Army ASTP personnel (8). About half of these were given one dose of influenza virus vaccine types A and B prepared as has been described, while the other half were given saline as a control. Both treatments comprised a one-dose hypodermic injection of 1 cc. It was observed that the incidence of clinical influenza was markedly lowered in the immunized group as compared to the control group, the actual figures being about one case in the immunized to 3.2 cases in the non-immunized. This practical showing against the natural disease as it appeared last year, together with good immunizing capacity of purified and concentrated influenza virus vaccine in human volunteers who later received active virus by nasal spray, have increased interest in further use of such vaccine in advance of the next epidemic of influenza. The type or types of influenza virus which may cause the next epidemic are of course unpredictable.

Summary

1. The main properties of epidemic influenza virus have been reviewed.

2. Influenza antiserum and its possible limited use in a prophylactic way have been referred to.

3. Preparation of influenza virus on a large scale and its conversion into vaccine have been described stepwise.

4. Immunizing action of purified influenza virus vaccine, types A and B, as prepared on a large scale, has been shown experimentally by results obtained in Swiss mice.

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Table 1. Hemagglutination Test of Influenza Virus

Final virus dilution	1:8	1:16	1:32	1:64	1:128	1:256	1:512	1:1024	1:2048	1:4096
Virus dose	(1-4) 1.0 cc.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2% Chicken red blood cells	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Room Temperature One Hour										
PR8A Virus	++++	++++	++++	++++	+++	++	+	0	0	0
Weiss A Virus	++++	++++	++++	++++	++	+	0	0	0	0
Lee B Virus	++++	++++	++++	++++	++	+	0	0	0	0

Table 2. Hemagglutination Test of Influenza Virus Strains to Check Strain type.

Final dilution of serum	1:10	1:20	1:40	1:80	1:160	1:320	1:640	1:1280	1:2560	
Serum dose	(1:2.5) 0.5 cc.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
Virus dose*	0.5 cc.	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
Room Temperature Five Minutes										
2% Chicken R.B.C.	1.0 cc.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
Room Temperature One Hour										
PR8A Chicken Anti-serum†	0	0	0	0	0	+	+++	++++	++++	PR8A virus‡
	0	0	0	0	+	+++	++++	++++	++++	Weiss A virus
	++++	++++	++++	++++	++++	++++	++++	++++	++++	Lee B virus
Weiss A Chicken Anti-serum	0	0	+	++	+++	++++	++++	++++	++++	PR8A virus
	0	0	0	0	++	+++	++++	++++	++++	Weiss A virus
	++++	++++	++++	++++	++++	++++	++++	++++	++++	Lee B virus
Lee B Chicken Anti-serum	+++	++++	++++	++++	++++	++++	++++	++++	++++	PR8A virus
	++	++++	++++	++++	++++	++++	++++	++++	++++	Weiss A virus
	0	0	0	0	0	+	++	++++	++++	Lee B virus

* Virus dose was eight 50 per cent hemagglutinating units.

† Specific chicken antiserum prepared by injecting chickens with two intraperitoneal doses of 5 cc. of virus, with an interval of a week between the doses, then bleeding the chickens a week after the last dose.

‡ The three viruses at different passages were assigned three section code numbers. The first or F section denotes the number of ferret passages; the second or M section denotes the number of mouse passages; the third or E section denotes the number of egg passages. In this experiment we used PR8A virus F198-M593-E14; Weiss A virus F3-M32-F21; and Lee B virus F8-M137-E58.

Table 3. Hemagglutination Test of Concentrated Influenza Lee Type B Virus Lot No. 734

Final virus dilution	1:8	1:16	1:32	1:64	1:128	1:256	1:512	1:1024	1:2048	1:4096
Virus dose	(1-4) 1.0 cc.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2% Chicken red blood cells	1.0 cc.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Concentrated virus	++++	++++	++++	++++	++++	++++	+++	++	+	0
Supernatant discard	++++	+++	++	+	+	0	0	0	0	0

Table 4. Mouse Immunity Test Protocol of Influenza Virus Vaccine

PR8A virus (mouse-lung suspension)*	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
Mice immunized with 10^{-2} dil. of vaccine	5, 5, 5 S, S, S	6, 7, S S, S, S	S, S, S S, S, S	7, 8, S S, S, S	0	0	0
Non-immunized mice	0	0	0	5, 5, 5 6, 6, S	6, 6, 6 7, 7, 9	8, 8, 8 10, S, S	8, S, S S, S, S

Weiss A virus (mouse-lung suspension)*	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
Mice immunized with 10^{-2} dil. of vaccine	6, S, S †, S, S	S, S, S S, S, S	5, S, S S, S, S	S, S, S S, S, S	0	0	0
Non-immunized mice	0	0	0	6, 6, 7 7, 8, 9	7, 8, 8 9, 9, S	9, 9, S S, S, S	8, 9, S S, S, S

Lee B virus (mouse-lung suspension)*	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}
Mice immunized with 10^{-4} dil. of vaccine	8, S, S S, S, S	S, S, S S, S, S	S, S, S S, S, S	S, S, S S, S, S	0		
Non-immunized mice	0	5, 7, 8 9, 9, S	5, 8, 9 9, S, S	6, 9, 10 S, S, S	S, S, S S, S, S		

Number indicates day of death of individual mouse.
"S" indicates survival ten days.
* The three viruses, as mouse-lung suspensions in dilutions indicated, were given intranasally.
† One mouse killed accidentally.

Morphological Characteristics of a Purified Thermophilic Cellulose Decomposing Culture

D. B. PRATT, Purdue University

A culture which will decompose cellulose at 65° C. may be readily obtained from the fecal material of ruminants. However, the isolation of the actual cellulose destroyer has not yet been satisfactorily accomplished. Many claims to success have been made, none of which has been generally accepted. The nearest approach to an acceptable pure culture is the one which is obtained from the clear zones on a plate containing finely divided cellulose. These plates are most satisfactory when incubated aerobically in a moist chamber according to the method described by Murray (1). These cultures have not been considered pure chiefly because no well defined colony may be observed and because of their marked heterogeneous nature. They may at best be termed purified.

The purpose of this work was to obtain information regarding the morphological development of such a culture. The possibilities of a life cycle or of a synergistic relation have been mentioned by previous workers to explain their failure to isolate pure cultures of the organism. A study in the development of a purified culture would possibly be helpful in determining the validity of these ideas. In this paper no attempt will be made to correlate the experimental facts with either of the above.

In brief, the idea of the experiment is this: if identical tubes are inoculated from an old culture and then pasteurized all of the cultures should be the same in that the forms of organisms would all be in a heat resistant stage. This would give a uniform starting point from which the morphological development could be observed.

Procedure

The experiment was carried out in culture tubes 125 mm. x 15 mm. These tubes were thoroughly cleaned, using chromic acid cleaning solution, and were rinsed in distilled water several times. In each tube 0.15 grams of filter paper was placed. This filter paper had been ground in a hammer mill. Ten milliliters of a peptone mineral salt solution were added to each of the tubes. These were plugged with cotton and autoclaved for 20 minutes at 15 lbs. pressure. After autoclaving the column of liquid is about 75 mm. in height and that of the cellulose which is at the bottom is about 20 mm.

These tubes were inoculated from a culture 9 days old which had completed its activity. The tubes were immersed in boiling water for ten minutes, cooled immediately, capped with tin foil and placed in the incubator at 65° C. After 12 hours two of the tubes were removed and smears were made from the material at the top and from that at the bottom of the tube. This was repeated at twelve-hour intervals until ninety-six hours of incubation had elapsed. Simple stains were made

using glycerated carbol fuchsin. The gram stains were carried out according to the Hucker modification, and a modified Dorner method was used for the spore stains.

Observations

The fermentations were typical in all of the tubes. At the end of 12 hours a white surface and subsurface growth was visible while the lower portions of the tube were apparently free of organisms. Stains from the upper portion showed large rods of uniform diameter, these rods were found in chains and clusters. Rods of varying length were observed in the same chain. These were gram variable and showed a tendency to be gram positive. The preparations from the lower sections contained a few of the large forms but a filamentous form seemed to predominate. This was very thin and extremely flexible. It attained lengths of 20 microns in some cases. The filaments are definitely gram negative in character.

The surface growth became progessively heavier and at the end of 36 hours had spread throughout the medium. The microscopic pictures

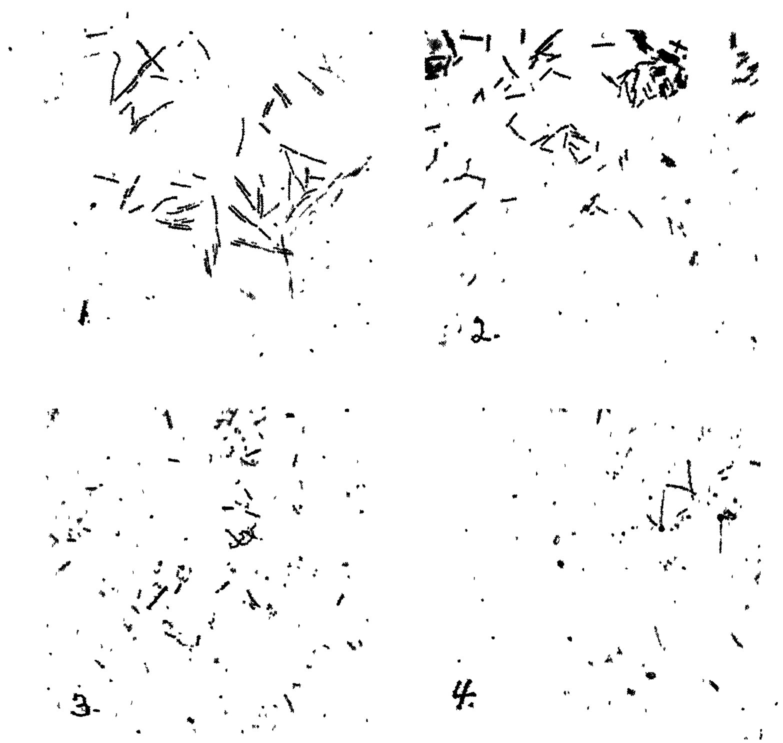

Fig. 1. Progressive development of morphological types found in the fermentation of cellulose by a purified thermophilic culture. 1) Top, 12 hours. 2) Top, 36 hours. 3) Bottom, 36 hours. 4) Bottom, 48 hours.

at the end of 24 and 36 hours were similar. The upper portions contained uniform rods in large numbers. These rods were approximately 8 microns long and 1 micron in width. These were heavily stained with the simple stain and showed a strong tendency to be gram positive. The bottom portions were very heterogeneous. Short filaments, long filaments, and the uniform rods as observed at the surface were all present in considerable numbers. In addition irregular shaped particles of about 1.5 microns in diameter were found. For convenience these have been termed Amorphous cocci. The evolution of gas and the formation of a yellow pigment began some time between 36 and 48 hours. This is the usual evidence of the cellulose digestion. In some cases the cellulose was held at the surface of the media by the rapid evolution of gas. The microscopic picture was that of an actively digesting culture as it is usually observed. The types from the top and the bottom were mixed and the surface no longer gave a uniform appearance. Of the filaments only the shorter ones 3-4 microns seemed to be found in the upper part. The longer filaments seemed to remain in the lower portions of the tube. At the bottom were also found filamentous rods of about ten microns in length and less than .5 microns in diameter. These bore a completely terminal oval spore 2-3 microns in length and 1.5-2.5 microns in diameter. This spore was deeply stained with the simple stain and was variable in its reaction to the gram stain. The spore stain was also very obscure. The spores held the stain only weakly if at all against the action of the nigrosin. With the exception of the spores the culture was gram negative. Little change could be observed in the microscopic picture after 60 hours. The evolution of gas continued vigorously and the cultures remained agitated.

This evolution of gas had stopped after 72 hours of incubation and the cellulose residues settled to the bottom of the tubes. No visible change occurred for the duration of the experiment. The uniform rods seemed to dominate the upper parts again and the bottom is more or less a mixture of the filamentous forms, rods, amorphous cocci, spore bearing filaments and free spores. These spores remained variable to the gram and spore stains even in the older cultures. The Amorphous cocci were numerous and were evenly distributed in the medium. This was the case until the end of the observations.

In the course of the experiment it was readily observed that the organisms could be divided into two groups according to their staining characteristics. The large uniform rod and the oval spore were both stained heavily with the simple stain and were the only organisms which exhibited any tendency to be gram positive. The filamentous forms and the Amorphous cocci were only slightly stained. In fact, the safranine used as a counterstain for the gram reaction had scarcely any effect on the organisms.

Summary

It seems apparent that two zones of development function in such a tube culture. One of these is near the surface and the other is near the cellulose fibers at the bottom. At the top large uniform rods develop and in the bottom a more filamentous form. "Amorphous cocci" were

observed first in the bottom and later throughout the media. These organisms were mixed thoroughly by the evolution of gas. Filaments bearing a large terminal spore were found after 48 hours. This spore is not typical in its staining reactions. Thus the large oval body cannot properly be termed a spore. The development of the culture has been followed and the evolution of gas accounts for the mixture of types which are usually observed.

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BOTANY

Chairman: B. H. SMITH, Indiana State Teachers College

Professor R. E. Girton, Purdue University, was elected chairman of the section for 1945.

A trial-balance sheet for the respiration of excised maize roots. RAYMOND E. GIRTON, Purdue University.—The respiration of sterile excised maize roots was measured in terms of carbon-dioxide production for periods exceeding 100 hours. Losses in organic matter by the roots were determined for these respiration periods. From the data thus obtained, the amounts of carbon dioxide produced per gram of organic matter consumed were calculated. These values were compared with those obtained from generalized equations for respiration based upon different assumed respiratory substrates.

The existence of physiological strains in the myxomycete Physarum polycephalum Schw. WILLIAM D. GRAY.—The earlier reports concerning the existence of physiological strains among species of myxomycetes are reviewed and evaluated on the basis of more recent findings. Applying Torrend's fusion test and using a technique which precluded possible interference with fusion of plasmodia by exotoxins excreted by the plasmodia, it has been found that the common myxomycete, *Physarum polycephalum* Schw., is composed of a number of strains so distinct that their plasomdia will not fuse. Among eight plasomdial cultures from different sources which have been examined to date, three distinct strains have been found.

A study of lake filling and bog formation. J. E. POTZGER, Butler, University and IRA T. WILSON, Heidelberg College, Tiffin, Ohio.—The old, and still commonly prevalent conception of writers of textbooks and scientific articles, is that lakes progress in their filling to bog stage by a centripetal process, which in the closing stages frequently results in a small central pond surrounded by a more or less solidified mat. According to such a theory it would, theoretically, make no difference where in a basin a boring for pollen analysis would be made to obtain a complete pollen profile, one beginning with the earliest plant invaders. Experience showed, however, that borings made on the upper slope of a bog or lake basin had truncated lower sections of a pollen profile, indicating that filling there began later than in the deeper portion. Using a complete pollen profile (one which showed the earliest spruce period) from a given bog or lake as "standard," pollen profiles from borings in line transects across the basin were compared with the "standard," and time of filling was indicated by the progress of succession shown in the pollen profiles. Records from seven lakes and eight bogs indicate that as a whole lakes begin filling centrifugally, i.e. the deepest part of a basin,

or the various depressions in a complex basin, like that of Tippecanoe Lake, fill first. Only after shallowing of the basin does centripetal filling begin. Where a bog mat forms it is in a late stage of the "verlandung" process. For pollen workers it is, therefore, very essential that borings be made in the deepest part, or parts of a bog or lake.

Post-glacial history of the lake forest type of formation. J. E. POTZGER, Butler University.—The lake forest is a transitional type of formation where species of Pinus and southern deciduous trees, associated with Tsuga, constitute the vegetation complex. Distribution of the northern and southern elements is apparently controlled by edaphic factors. The aim of the study was to determine by aid of 24 pollen profiles how far south this formation type extended during post-glacial times. Results show that the lake forest type is of comparatively recent origin, succeeding a decided pine dominance, which earlier had succeeded Abies and Picea climax forest. This is true at least for an area extending from northern Indiana northward, and from western Minnesota to New England (the area covered by the 24 pollen profiles).

If we designate the pine-deciduous forest complex as characteristic of the lake forest type, it ranged from northern Indiana northward and northeastward. If, however, we designate Tsuga and Betula as key genera in the deciduous forest element then the lake forest varied little in geographical range from that of today, but had formerly a more decided eastward extension to northern New Jersey and New England.

The Utilization of Staled Media by Fungi

C. L. PORTER, Purdue University

The term "staling" was suggested by Dr. Wm. Brown, of the University of London, to describe the condition of a medium that could no longer support the growth of a fungus in a normal manner. A medium was "stale" according to Brown when by-products of fungus growth accumulated to such an extent that further fungus development was inhibited. This occurs eventually whether the same or a different fungus is cultured in a stale medium.

Staling products produced by one organism may inhibit another organism that is growing in the same medium. Thus, Dr. Fleming discovered quite accidentally that *Staphylococcus aureus* was inhibited by the growth products of *Penicillium notatum*. There has existed a difference of opinion as to the cause of staling. It is fairly evident that a medium may become stale for various reasons. In the *Staphylococcus aureus-Penicillium notatum* reaction it is quite obvious that the metabolic product, penicillin, is the cause of staling and the consequent inhibitory action. Other metabolic products, as well as unfavorable pH reactions, unfavorable concentrations, or the exhaustion of certain essential nutrients from the medium, might cause staling.

The author has spent years in the investigation of the phenomena associated with staling and numerous reports have been made to the Academy. The research presented here is a continuation of research previously reported.

How stale are unsterilized media after they have been exposed at room temperatures for 24, 72, 120 and 240 hours. The studies here reported give at least a partial answer.

The medium used in this investigation was potato degtrose agar, made from an infusion from two hundred grams of potatoes with twenty grams of dextrose and 15 grams of agar added for each one thousand cc. of distilled water. The final pH of this medium is 5.6. After this medium was prepared in accordance with the formula it was tubed and the tubes were plugged with cotton. The tubes of media were divided into several lots. Lot 1 was sterilized immediately. Lot 2 was permitted to remain at room temperatures for 24 hours before it was sterilized. Seventy-two hours elapsed before lot 3 was sterilized. Lot 4 remained at room temperatures 120 hours before sterilization. Two hundred forty hours was the pre-sterilization period for lot 5. At the close of these various periods of time each lot was sterilized in the autoclave at fifteen pounds pressure for twenty minutes. These various media were dispensed to sterilized petri plates and after the media were hardened, the surface of each medium was streaked with *Staphylococcus aureus* or *Penicillium notatum*.

The organisms used to test the staleness of the various media were

chosen because of the wide publicity that has been given to them recently and because this work with staled media fits into a pattern of experiments that we are making with these test organisms.

Following 24 hours of chance exposure the potato dextrose agar showed little visible change. It was still unclouded and there was no visible fungus growth. There were a few small and submerged colonies of bacteria and there were a few bubbles in the medium indicating the presence of some gas-forming organisms.

The medium exposed 72 hours exhibited quite clearly the presence of gas-forming bacteria. Penicillia and some other filamentous fungi were in evidence on the surfaces of the media in the tubes. Medium was cloudy.

After 120 hours of exposure there was a definite fungus mat on top of the medium in each tube, and the medium was cloudy.

The medium exposed for ten days (240 hours) had been host to a succession of fungi and bacteria, beginning with deep gas-forming bacterial colonies, followed by surface growths of Penicillium and Aspergillus, and miscellaneous organisms that formed a definite fungus mat at the surface. There later developed on this mat a vigorous growth of Rhizopus and Mucor. The medium was cloudy and filled with granular deposits. There was so much debris in the 240-hour tubes that it was necessary to filter the medium before autoclaving.

Colorimetric pH readings were taken of the various media. The results of these reading follow: 24 hours exposure—unchanged (5.6); 72 hours exposure, 5; 120 hours exposure, 4; 240 hours exposure, 3.

Results of growth on the various media were as follows:

Length of exposure	Growth of P. notatum	Growth of Staph. aureus
None (check)	vigorous	normal
24 hours	"	"
72 hours	"	definitely inhibited
120 hours	"	no growth
240 hours	"	

The medium staled by 240 hours of contamination was so acid that after it had been sterilized it remained in a liquid condition even at low temperatures. This liquid was inoculated with *Penicillium notatum*, but the cloudy, soupy condition made it impossible to judge whether it would support a growth of *Staphylococcus aureus*.

Thus far in this investigation the media have been staled by accidental contaminations. Since there are so many possible explanations of the cause of staling, chance contaminations increase the unknown factors considerably. In order to eliminate some of the uncertainties, sterilized potato dextrose agar was inoculated with *Bacillus brevis*. This organism made a satisfactory growth on the surface of the agar in the inoculated tubes. Nine-six hours following the inoculation of potato dextrose agar with B. brevis these tubes of agar were sterilized and the sterilized agar was inoculated in plates with *Penicillium notatum* or with *Staphylococcus aureus*. *P. notatum* grew uninhibited but Staph. aureus made no growth. B. brevis was selected for this phase of the

investigation because B. brevis, a soil organism, is one of the bacteria much used recently in the production of antibiotic substances.

The research here recorded justifies the following conclusions:

1. *Penicillium notatum* is apparently unaffected by a staled medium.

2. *Staphylococcus aureus* is quite sensitive to staling products.

3. A staled medium becomes progressively more acid. The lowering of the pH affects the growth of most bacteria.

4. Bacillus brevis serving as the staling agent affected the growth of the two test organisms in the same manner that growth had been affected by chance contaminating organisms.

5. A medium remaining unsterilized is not a medium that will support the normal development of bacteria, nor probably of most fungi.

Epidermal Characters in Fraxinus

JONATHAN W. WRIGHT, Purdue University

Difficulty is often encountered in the identification of sterile specimens of some of the ashes of eastern America. Particularly hard to separate from each other are leaves of the Biltmore white ash (*F. biltmoreana* Beadle) and the pumpkin ash (*F. tomentosa* Michx.), as well as entire or nearly entire specimens of white ash (*F. americana* L.) and the green ash (*F. pennsylvanica* Marsh. var. *lanceolata* (Borkh.) Sarg.). These species may be easily separated by certain microscopic characters of the lower epidermis. As these characters have not heretofore been used, they are here described in detail for the ashes found in eastern America.

Methods

The epidermal characters were studied from colodion peels made from the lower leaf surface of herbarium specimens. The peels were made by applying a solution of colodion in butyl acetate plus 5 per cent butyl alcohol to the under surface of the leaf (Sax and Sax, 1937). Rather thin solutions were found satisfactory with all but the white ash and the Biltmore white ash. With these, a much more viscous solution was needed, in order to provide a film tough enough to be removed from the leaf. It was found unnecessary to remove the pubescence prior to the application of the collodion, as the unicellular hairs did not interfere with the observation of the peels. The collodion film was dried in the open air. Upon drying, the peels were affixed to microscope slides by a drop of the collodion solution at each corner of the peel. No cover glasses were added to the mounts. Stomata measurements were made from camera lucida drawings using a 10x ocular and a 44x objective.

According to Solereder (1908) "the characteristic form of hair in this order (family) is that of peltate trichomes of variable size, having a unicellular stalk and a shield which is usually divided by vertical walls only. These peltate hairs are usually grandular, and in *Olea* alone having a clothing function; . . ." These peltate hairs (Figs. 6, 7) were of general occurrence over the entire lower surface of the leaf in all the species studied as well as in several of our western ashes and appeared of little diagnostic value. They are umbrella-shaped structures of slightly less than twice the diameter of the stomata. The stalk is usually very short, and the shield is composed of from 4 to 8 cells. Unicellular hairs, often reaching 0.5 mm. in length are also found, most commonly occurring along the midrib. It is these unicellular hairs which give the velvety appearance to the leaves and twigs of *F. biltmoreana* and *F. pennsylvanica*. The cells of the lower epidermis of ash generally have an irregular outline.

SPECIES KEY BASED ON EPIDERMAL CHARACTERS

a. Stomata oval-acute, variable in size; epidermal ridges numerous, usually obscuring the impression of the cell outlines on a leaf peel.................... .... subsection *Melioides*

b. Stomata 15-30 microns long, not grouped; cells with coronulate papillae (except those of veins); peels removed with difficulty

.... 1. *F. americana*

.... 2. *F. biltmoreana*

bb. Stomata in groups of 10-12, separated by small veinlets with rectangular cells; epidermal ridges numerous within groups; no coronulate papillae; peels removed easily.

c. Stomata 15-24 microns long ... . 3. *F. pennsylvanica*

. ... .4. *F. caroliniana*

cc. Stomata 22-34 microns long . . ..5. *F. tomentosa*

aa. Stomata oblong, of uniform size, not grouped; epidermal ridges usually emanating only from stomata, not obscuring impression of cell wall on leaf peel; peels removed easily .subsection *Bumelioides*

d. Epidermal ridges usually present in vicinity of all stomata; stomata 14-20 microns long... .... 6. *F. nigra*

dd. Epidemal ridges often absent; stomata 11-16 microns long

....7. *F. quadrangulata*

The two subsections of the genus present in eastern America are as easily distinguishable by the appearance of their leaf peels (Figs. 4, 7) as by their gross morphology. In subsection *Melioides*, containing white ash and red ash (*F. pennsylvanica* Marsh.) the stomata[1] are oval acute, under high power (x 440) looking much like eyes. They are relatively large, and quite variable in size, even on the same leaf. In the red ash especially it is usual to find a variation of 50 per cent in guard cell length within the same microscope field. This subsection is also characterized by abundant fine epidermal ridges which obscure the cell outlines. These ridges give all the species a whitish cast to the under leaf surface when viewed by the unaided eye.

Leaf peels of white ash (Figs. 1, 2) and Biltmore white ash are easily distinguishable from those of our other eastern species by their "coronulate papillae united by a network of ridges" (Solereder, 1908). Fine epidermal ridges, visible only under high magnification, cover the entire lower leaf surface with the exception of the veins. These ridges end in the centers of the cells, curving upward and outward, giving the papillae their coronulate appearance. This outward curving of the ridges gives the leaf an exceptionally firm grip on the leaf peel, making the removal of the latter difficult. The roughness caused by these papillae causes the under surface of the leaf to be much whiter than that of any of our other species when viewed in the field. The papillae somewhat obscure the stomata, making their observation and measurement difficult. When examined under low power (x 100) the peels have the appearance

[1] The term stomata is here used to denote not only the openings in the leaf surface but the guard cells as well.

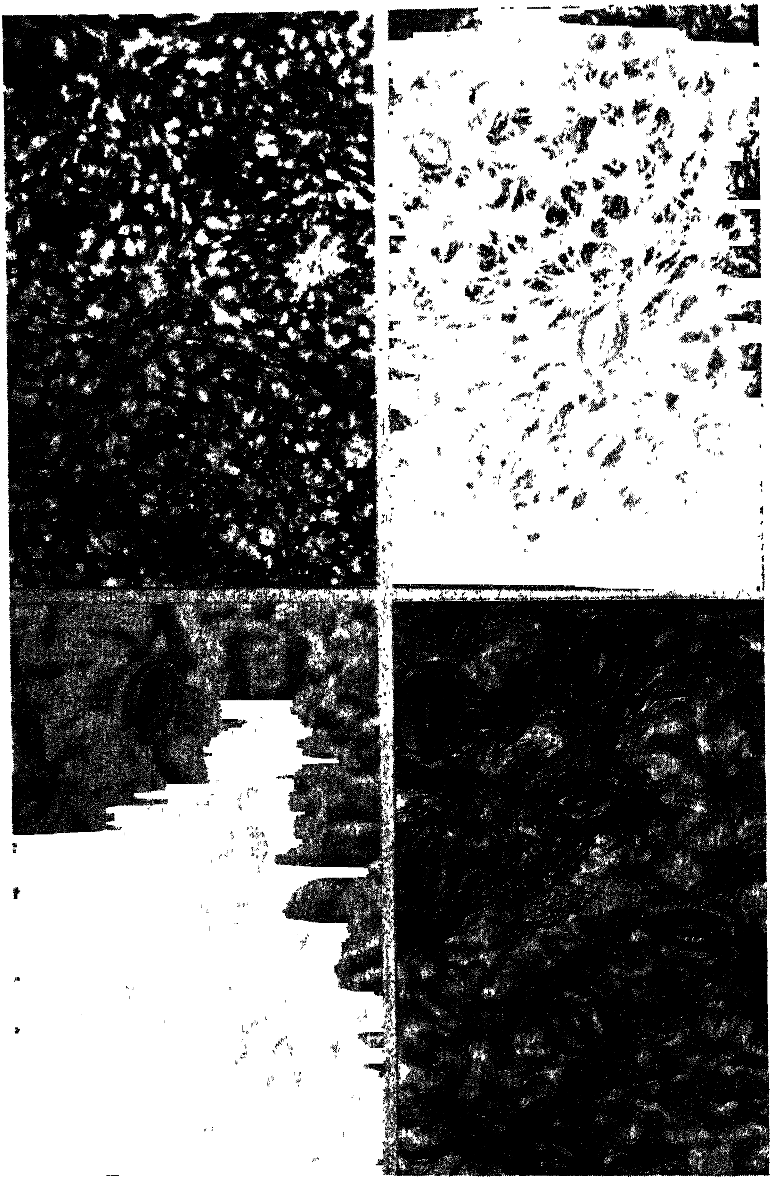

Plate I

Figures 1-4. Photographs of collodion peels of the lower epidermis of species of *Fraxinus*. Fig. 1. Diploid *F. americana* (mature tree). At low magnifications the coronulate papillae and anastomosing ridges give to the peel the appearance of a reticulum. (x 250). Fig. 2. Diploid *F. americana* (mature tree). At higher magnifications, the tips of the coronulate papillae are out of focus, but the ridges running between cells can be clearly seen. Note the considerable variation in size of the individual stomata which is typical of all species of the subsection *Melioides*. (x 490). Fig. 3. Diploid *F. americana* (two-year tree). In young trees the papillae are lacking and the ridges are not well developed (x 490). Fig. 4. *F. carolininana*. Under high magnification, both red and Carolina ash show numerous epidermal ridges radiating out from the stomata, giving the appearance of eyes with long curly eyelashes (x 490).

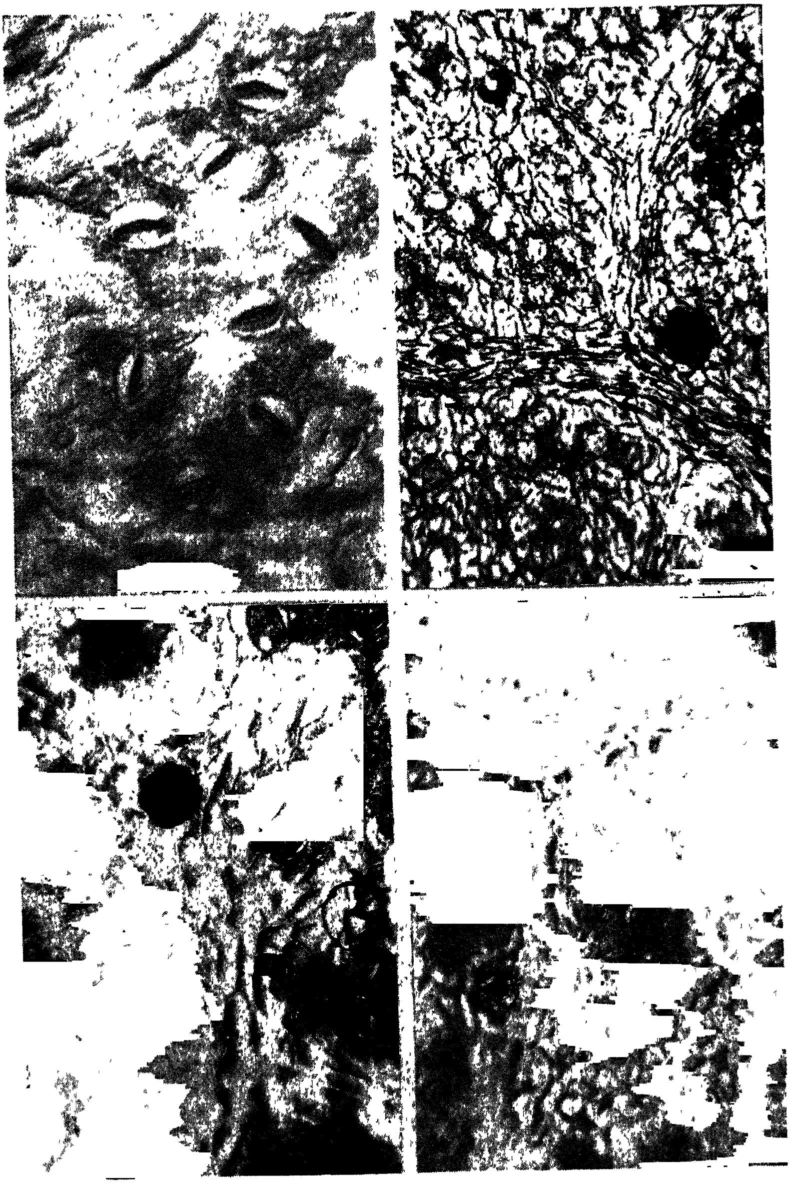

Plate II

Figures 5-8. Photographs of collodion peels of the lower epidermis of species of *Fraxinus*. Fig. 5. *F. pennsylvanica*. The stomata are characteristically grouped. There are no coronulate papillae, and the epidermal ridges are nearly confined to the portions of the leaf within stomata groups. In the left center is a peltate hair, characteristic of the entire family Oleaceae. Peels of *F. caroliniana* are indistinguishable from peels of *F. pennsylvanica*. (x 250). Fig. 6. *F. tomentosa*. Leaf peels of the pumpkin ash are distinguishable from those of red ash by the larger stomata size. (x 250). Fig. 7. *F. nigra*. The stomata are of uniform, small size in both black and blue ash, and are evenly distributed over the surface of the leaf. They are more numerous than in the other species studied. In the center is a peltate hair. (x 250). Fig. 8. *F. nigra*. Under high magnification, black ash stomata are oblong. Epidermal ridges are lacking, or emanate only a short distance from the stomata. (x 490).

of a reticulum, and the stomata are hardly visible. The cell outlines are usually not visible under either high power or low power. Unfortunately, this character cannot be used in the identification of young trees, since white ash seedlings up to two years of age lack the papillae, although they do have some fine ridges emanating from the stomata (Fig. 3).

Leaf peels of the Mexican *F. papillosa* Lingelsh. are similar to those of white ash.

The stomata of *F. americana* and *F. biltmoreana* are variable in density from 30 to 200 per square millimeter on different individuals, although the density is remarkably constant on peels made from any one tree. An attempt was made to correlate number of stomata per unit of area with chromosome number within the species, as Sax (1938) had done for different species of ash. This was impossible, as there was no constant relation between the two variables. However, stomata size did prove a reliable criterion of polyploidy within *F. americana*. The base number in the genus is n = 23 (Sax and Abbe, 1933). Wright (1944) found a polyploid series in the southern portion of the species' range. Stomata measurements made on peels of trees with known chromosome number revealed significant differences between the stomata of the plants with different chromosome number (Table 1). Stomata size is a most

Table I.

Length of stomata guard cells in diploid and polyploid *Fraxinus americana*

Chromosome number	Number of collections included in mean	Mean length, guard cells Microns	Limits within which a collection mean may vary (P = ± .05)* Microns
		PROGENY†	
2n	14	18.8±0.2‡	17.5-20.0
4n	2	21.6±0.3	20.1-23.0
6n	4	24.2±0.6	22.5-25.8
		PARENTS§	
2n	11	18.2±0.3	16.3-20.1
4n	2	22.5±1.1	20.2-24.8
6n	4	23.7±0.4	21.2-26.2

* Calculated by assuming a coefficient of variability equal to that found in the diploids.

† Mean lengths and limits of variability of mean determined from samples of 100 stomata (20 stomata on a single peel from 1 leaf on each of 5 seedlings).

‡ Standard error.

§ Mean lengths determined from samples of 40 stomata (two peels from each tree), and limits of variability of mean from samples of 20 stomata (one peel from each tree).

reliable criterion of polyploidy for young trees grown under constant conditions in the nursery, for which it is possible to separate with certainty diploids, tetraploids and hexaploids. It is less reliable in ordinary field-grown material, in which it is only safe to distinguish between diploids and polyploids.

The lower surface of *F. pennsylvanica* (Figs. 4, 5) and *F. caroliniana* are similar in appearance, lacking entirely the papillae so characteristic of *F. americana.* The stomata are aggregated into groups of ten or twelve. These groups are separated by small veinlets composed of rectangular cells without epidermal ridges. In the areas within stomata groups the cells are irregular in outline and usually have abundant epidermal ridges although in a few specimens these are lacking. The ridges seems to emanate from the stomata, which have the appearance of eyes with long wavy eyelashes.

The lower epidermis of *F. tomentosa* (Fig. 6) is similar to that of the two preceding species in all quantitative characters. However, with a little practice, peels of this tree may be distinguished by cell size, the stomata being about 1½ times as large as those of either red or Carolina ash. They are less abundant, having a density of 120 to 300 per square millimeter.

The stomata of *F. nigra* (Figs. 7, 8) and *F. quadrangulata*—our two species of the subsection *Bumelioides*—are oblong, and of a smaller and less variable size than are those of the subsection *Melioides.* The guard cells are relatively broader and less pointed. The stomata are very abundant (up to 1000 per square millimeter), and are uniformly distributed over the entire lower leaf surface with the exception of the larger veins, in contrast with those of the subsection *Melioides.* The minute epidermal ridges when present emanate only short distances from the stomata, rarely obscuring the impression of the cell walls on the peel. In *F. quadrangulata*, which has the smallest and most abundant stomata of any of our species, the ridges are almost entirely absent. The differences between epidermal peels of blue and black ash are too slight to make positive separation possible.

It should be made clear that these epidermal characters are of little use in field identification, for it is impossible for a collector to carry with him the equipment necessary for making and examining the peels. (In any case, the peels are best made from dried material.) Nevertheless, they should be of great help to the taxonomist classifying specimens in the herbarium. By their use difficult sterile specimens may be referred definitely to one species with more certainty than is possible by an examination of gross morphology alone. Too, further study of the leaf peels of living material should help to clarify the relation between living and fossil species of *Fraxinus.*

The epidermal characters are most useful in the separation of sterile or male specimens of *F. americana* and *F. pennsylvanica* var. *lanceolata,* normally distinguished by the fruits. Leaves of these two species are often quite indistinguishable from gross morphology; a peel of the white ash leaf can only be removed with great difficulty, and will reveal the coronulate papillae, absent in the latter. Likewise, non-fruiting specimens of *F. biltmoreana* and *F. tomentosa* are similar in gross morphology, but

are easily distinguishable upon microscopic analysis by the presence or absence of the coronulate papillae. Unfortunately, the peels are of no help in distinguishing leaves of the green ash and the Carolina ash, which are also hard to separate on gross morphology, nor can they be used to separate black from blue ash.

Acknowledgements

The writer wishes to acknowledge with gratitude the helpful criticism of Professors P. R. Gast and Karl Sax, under whose guidance the plants were grown and the counts were made. The writer is also indebted to the curators of the Gray Herbarium, Arnold Arboretum, New York Botanical Garden, U. S. National Herbarium, and the Duke University Herbarium.

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Indiana Plant Distribution Records, V. 1944

This is a continuation of the series of annual reports intended to keep Dean's "Flora of Indiana" up to date. The report comprises three sections, viz. "SPECIES", giving new county records with the location of confirming specimens; "NOMENCLATORIAL CHANGES" in which an attempt is made, within the limits and in the spirit of conservative taxonomy, to keep the "Flora" up to date in plant names; "DELETIONS" in which known previous errors are corrected.

Species

Genera are listed in the order used in the "Flora" and species are given in alphabetical order within the genera. Symbols following the counties indicate the herbaria in which confirming specimens have been deposited. Species, varieties or forms new for the state are given in bold face type and these together with name changes are followed by literature references. Cases of doubt whether a species, newly found within the state, will become a part of the state flora are preceded by an asterisk.

The specimens listed below have been collected by the following collectors: Butler University (B): Charles C. Deam, Ferry R. Clark, Ray C. Friesner, Scott McCoy, C. M. Palmer, and J. E. Potzger; Deam Herbarium (D): Charles C. Deam, Ralph Kriebel, J. E. Potzger, and Paul Weatherwax; DePauw University (DP): Charles M. Ek, E. J. Grimes, Scott McCoy, Arthur Ogilvie, and T. G. Yuncker; Huntington College (Hu): Fred Loew; Indiana University (IU): Paul Weatherwax; Kriebel Private Herbarium (K): Ralph Kriebel; New York Botanical Garden (NY): Charles C. Deam and F. W. Johnson; University of Michigan (Mi): J. F. Baird, H. H. Bartlett; Missouri Botanical Garden (Mo): Charles B. Heiser; Purdue University (P): H. B. Dorner; U. S. National Herbarium (N): Ray C. Friesner, J. E. Potzger.

Other symbols used are: University of Florida (Fl).

The committee maintains a card file showing published distribution of each species within the state. Botanical workers needing such information, may obtain distribution maps of any species, recorded in the "Flora" or subsequently added in these reports, by requesting same from the secretary of this committee.

Botrychium virginianum, Fayette (B). *Cystopteris fragilis* v. *protrusa,* Fayette (B). *Dryopteris goldiana,* Brown (B), Wayne (B). *D. thelypteris* v. *pubescens,* Delaware (B), Randolph (D, B). *Athyrium pycnocarpon,* Clay (DP). *Adiantum pedatum,* Huntington, (Hu). *Pteridium aquilinum* v. *latiusculum,* Delaware (B). *Equisetum laevigatum,* Marion (B).

Typha latifolia, Delaware (B). *Sparganium eurycarpum,* Randolph (B). *Potamogeton foliosus* v. *genuinus,* Jay (B) Randolph (B). *Triglo-*

chin palustris, Randolph (D, B). *Alisma subcordatum*, Delaware (B), Randolph (B, D). *Sagittaria latifolia* v. *obtusa*, Randolph (B).

Bromus inermis, Randolph (B). *B. latiglumis*, Randolph (B). *Glyceria septentrionalis*, Hancock (B), Randolph (B). *Poa compressa*, Delaware (B), Randolph (B). **P. nemoralis L.** Hitchcock, Grasses of U. S., 123., Marion (D, B, N). Collected by J. E. Potzger. *P. pratensis*, Fayette (B). *Eragrostis capillaris*, Shelby (B), *E. cilianensis*, Delaware (B), Jay (B), Randolph (B). *E. frankii*, Randolph (B). *E. hypnoides*, Randolph (D, B). *E. pectinacea*, Hancock (B), Randolph (B). *Phragmites communis*, Randolph (B). *Melica nitens*, Delaware (B). *Agropyron repens*, Delaware (B), Fayette (B), Hancock (B), Randolph (D). *A. smithii*, Henry (B). *Elymus riparius*, Randolph (B). *E. villosus*, Hancock (B), Harrison (B). *Calamagrostis canadensis*, Delaware (B), Randolph (B). *Agrostis alba*, Huntington (Hu). *A. palustris*, Delaware (B), Randolph (B), Wayne (B). *Phleum pratense*, Delaware (B), Randolph (B).

Muhlenbergia mexicana, Randolph (B, D). *M. setosa*, Randolph (B). *Eleusine indica*, Delaware (B), Randolph (B). *Spartina pectinacea*, Henry (B). *Phalaris arundinacea*, Hancock (B). *Leerzia oryzoides*, Huntington (Hu), Wayne (B). *L. virginicus*, Huntington (Hu), Wayne (B). *Digitaria sanguinalis*, Hancock (B), Randolph (B), Wayne (B). **Paspalum supinum** Bosc. Hitchcock, Grasses of U. S., p. 585. Knox (D, B, N). Collected by J. E. Potzger. *Panicum albermarlense*, Randolph (B). *P. capillare*, Randolph (B). *P. deamii*, LaPorte (B). *P. gattingeri*, Randolph (B), Wayne (B). *P. huachucae*, Fayette (B). *P. microcarpon*, Fulton (B). *P. scribnerianum*, Marion (B). *P. sphaerocarpon*, Steuben (B). *P. virgatum*, Henry (B). *Echinochloa crusgalli*, Hancock (B), Jay (B). *Setaria lutescens*, Hancock (B), Jay (B). *S. viridis*, Delaware (B). *Andropogon gerardi*, Randolph (D, B). *Sorghastrum nutans*, Randolph (B).

Cyperus aristatus, Randolph (D). *C. odoratus*, Randolph (D). *C. rivularis*, Hancock (B), Randolph (B). *C. strigosus*, Jay (B). *Scirpus atrovirens*, Delaware (B), Randolph (B). *S. validus* v. *creber*, Delaware (B), Huntington (Hu), Randolph (B). *Eleocharis obtusa*, Delaware (B), Marion (B), Randolph (D, B). *E. quadrangulata* v. *crassior* Gibson (D). *E. rostellata*, Randolph (D). *Scleria verticillata*, Randolph (D, B).

Carex frankii, Delaware (B). *C. hystricina*, Randolph (B). *C. lupulina*, Randolph (B). *C. muskingumensis*, Huntington (Hu.) *C. vulpinoidea*, Delaware (B), Randolph (B). *Symplocarpus foetidus*, Huntington (Hu). *Tradescantia subaspera* var. *typica*, Huntington (Hu). *T. virginiana*, Huntington (Hu). *Juncus brachycephalus*, Randolph (D, B). *J. torreyi*, Randolph (D, B).

Tofieldia glutinosa, Randolph (B). *Allium vineale*, Delaware (B), Hancock (B). *Smilacina racemosa* v. *cylindrata*, Fayette (B), Marion (B). *S. stellata*, Randolph (B). *Polygonatum canaliculatum*, Randolph

(B). *Trillium flexipes* Raf., Rhodora 46:16. 1944, Fayette (B). *Smilax herbacea*, Delaware (B), Randolph (B). *S. h.* v. *lasioneura*, Randolph (B). *S. hispida*, Fayette (B). *Dioscorea villosa*, Delaware (B). *Sisyrinchium graninodies*, Fayette (B). *Habenaria viridis* v. *bracteata*, Putnam (DP). *Spiranthes cernua*, Randolph (B). *Calopogon pulchellus*, Huntington (Hu).

Populus grandidentata, Marion (B). *P. tremuloides*, Randolph (B). *Salix bebbiana*, Randolph (D). *S. cordata*, Delaware (B), Hancock (B), Madison (B), Randolph (B). *S. discolor* var. *latifolia*, Randolph (B). *S. interior*, Madison (B). *S. lucida*, Randolph (B). *Juglans cinerea*, Clay (DP). *J. nigra*, Brown (DP), Fayette (B), Howard (B), Marion (B), Ohio (B), Randolph (B) Switzerland (B). *Carya cordiformis*, Fayette (B), Hancock (B), Randolph (B). *C. laciniosa*, Hancock (B). *C. ovata*, Fayette (B), Hancock (B), Huntington (Hu), Randolph (B). *Carpinus caroliniana* v. *virginiana*, Fayette (B). *Ostrya virginiana* v. *glandulosa*, Fayette (B). *Corylus americana*, Randolph (B).

Fagus grandifolia, Fayette (B). *Castanea dentata*, Putnam (DP). *Quercus alba*, Hancock (B). *Q. bicolor*, Fayette (B), Owen (DP), Randolph (B). *Q. borealis* v. *maxima*, Fayette (B). *Q. imbricaria*, Delaware (B). *Q. macrocarpa*, Fayette (B), Putnam (DP). *Q. velutina*, Delaware (B). *Ulmus americana*, Fayette (B), Hancock (B), Jay (B), Randolph (B). *U. fulva*, Fayette (B). *U. thomasi*, Hamilton (B). *Celtis occidentalis* v. *canina*, Huntington (Hu). *C. o.* v. *crassifolia*, Fayette (B), Hancock (B),. *Morus alba* v. *tatarica*, Fayette (B). *Humulus americana*, Randolph (B, D). *Laportea canadensis*, Fayette (B). *Boehmeria cylindrica*, Hancock (B), Randolph (D, B). *B. c.* v. *drummondiana*, Randolph (B).

Commandra richardsiana, Randolph (B). *Asarum canadense*, Randolph (B). *Aristolochia serpentaria*, Randolph (B). *Rumex acetosella*, Fayette (B). *Polygonum coccineum*, Randolph (D, B). *P. erectum*, Hancock (B). *P. hydropiper* v. *projectum*, Hancock (B), Randolph (B). *P. hydropiperoides*, Randolph (B). *P. lapathifolium*, Randolph (D). *P. neglectum*, Hancock (B). *P. persicaria*, Henry (B), Madison (B), Randolph (B). *P. sagittatum*, Randolph (D). *P. virginianum*, Randolph (D). *Chenopodium album*, Huntington (Hu). *C. botrys*, Delaware (B). *Atriplex patula* v. *littoralis*, Randolph (D). *Amaranthus blitoides*, Huntington (Hu). *A. retroflexus*, Huntington (Hu). *Acnida altissima*, Hancock (B). *Phytolacca americana*, Delaware (B). *Mollugo verticillata*, Fayette (B).

Arenaria serpyllifolia, Fayette (B). *Stellaria media*, Huntington (Hu). *Silene antirrhina*, Fayette (B). *S. cucubalus*, Marion (B). *S. regia*, Delaware (B). *Dianthus armeria*, Fayette (B). ***Saponaria ocymoides** L., Bailey Man. Cult. Plt., p. 265., Elkhart (B, NY). Collected by Charles M. Ek. *S. vaccaria*, Marion (B). *Caltha palustris*, Huntington (HU). *Ranunculus longirostris*, Hancock (B). *R. septentrionalis* v. *caricetorum*, Randolph (D, B). *Thalictrum dasycarpum*, Huntington (Hu). *Liriodendron tulipifera*, Fayette (B). *Asimina triloba*, Randolph

(B). *Sassafras albidum,* Delaware (B). *S. a.* v. *molle,* Hancock (B). *Thlaspi arvense,* Marion (B). *Sisymbrium altissimum,* Randolph (B). *S. officinale* v. *leiocarpum,* Delaware (B). *Brassica kaber* v. *pinnatifida,* Randolph (D). *Barbarea vulgaris* v. *arcuata,* Rhodora 45:304. Clinton (B), Hamilton (B), Howard (B), Jackson (B), LaPorte (B), Marion (B), Morgan (B). *Rorippa islandica* v. *microcarpa,* Randoph (D, B). *R. sessiliflora,* Delaware (B). *R. sylvestris,* Jay (B), Randolph (B, D). *Cardamine douglasii,* Huntington (Hu). *Camelina microcarpa,* Fayette (B). ***Descurainia sophia** (L). Webb. Amer. Midland Nat. 22: 487. 1939. Marion (B). Collected by Ray C. Friesner.

Polanisia graveolens, Delaware (B). *Penthorum sedioides,* Delaware (B), Hancock (B). *Saxifraga pennsylvanica,* Huntington (Hu). *Parnassia glauca,* Randolph (D, B). *Ribes americana,* Hancock (B). *Platanus occidentalis,* Jay (B). *Physocarpus opulifolius,* Randolph (D, B). *Amelanchier canadensis,* Huntington (Hu). *Rubus hispidus* v. *obovalis,* Cass (B), Elkhart (B), Grant (B), Howard (B), Ripley (B), Pulaski (B), Steuben (B). *R. occidentalis,* Fayette (B). *R. pubescens,* Kosciusko (B), Starke (B). *Potentilla fruticosa,* Randolph (D, B). *P. monspeliensis,* Fayette (B), Hancock (B), Randolph (B). *P. recta,* Fayette (B). *Filipendula rubra,* Madison (B), Randolph (D, B). *Agrimonia parviflora,* Randolph (D). *Rosa setigera* v. *tomentosa,* Delaware (B), Fayette (B). *Prunus serotina,* Fayette (B), Hancock (B), Randolph (B).

Cassia hebecarpa, Randolph (D, B). *Gleditsia traiacanthos,* Fayette (B), Randolph (D, B). *Melilotus alba,* Delaware (B), Fayette (B), Randolph (B). *M. officinalis,* Hancock (B). *Psoralea onobrychis,* Delaware (B). *Vicia cracca,* Cass (B), Marion (B), *Lathyrus palustris,* Randolph (B). *Amphicarpa bracteata,* Huntington (Hu). *Apios americana,* Huntington (Hu), Randolph (B). *Geranium carolinianum* v. *confertiflorum,* Marion (B). *Oxalis europea,* Randolph (B). *O. e.* f. *cymosa,* Hancock (B). *O. stricta,* Fayette (B). *Linum medium* v. *texanum,* Putnam (DP). *Zanthoxylum americanum,* Randolph (B). *Acalypha virginica,* Huntington (Hu). *Euphorbia corollata,* Delaware (B). *E. maculata,* Delaware (B), Jay (B). *E. supina,* Jay (B). *Rhus glabra,* Delaware (B), Randolph (D, B). *R. vernix,* Randolph (B, D). *Ilex verticillata,* Randolph (B). *Acer nigrum,* Fayette (B). *A. rubrum,* Hancock (B), Marion (B). *A. saccharinum,* Fayette (B). *A. saccharum,* Fayette (B), Randolph (B). *Aesculus glabra,* Randolph (B).

Ceanothus americanus, Delaware (B). *Vitis cinerea,* Delaware (B). *Parthenocissus inserta,* Randolph (D). *P. quinquefolia* f. *hirsuta,* Fayette (B). *Sida spinosa,* Hancock (B). *Hibiscus trionum,* Hancock (B). *Hypericum prolificum,* Randolph (B). *H. sphaerocarpum,* Hancock (B). *H. tubulosum* v. *walteri,* Owen (D, IU). *Viola eriocarpa* v. *leiocarpa,* Fayette (B). *Didiplis diandra,* Owen (D, IU). *Lythrum alatum,* Delaware (B). *Ludvigia alternifolia,* Putnam (DP). *L. a.* v. **pubescens** Palmer & Steyermark. Ann. Missouri Bot. Gard. 25: 772. 1938. Posey (D). Collected by Charles C. Deam. *L. palustris* v. *americana,* Delaware

(B), Hancock (B), Jay (B). *L. polycarpa,* Delaware (B). *Oenothera pycnocarpa,* Hancock (B), Jay (B), Randolph (B). *Gaura biennis,* Randolph (D, B).

Sanicula canadensis v. *typica,* Fayette (B), Hancock (B), Randolph (B). *Spermolepis inermis,* Marion (B). *Sium suave,* Hancock (B). *Oxypolis rigidior,* Randolph (D, B). *Pastinaca sativa,* Randolph (B). *Daucus carota,* Delaware (B), Jay (B), Randolph (B). *Nyssa sylvatica,* Adams (D, B). *N. s.* v. *caroliniana,* Gibson (D, K). *Cornus obliqua,* Hancock (B), Randolph (B). *C. racemosa,* Delaware (B), Hancock (B). *C. stolonifera,* Randolph (B). *Lysimachia longifolia,* Randolph (D, B). *Fraxinus americana* Adams (D, B). *F. lanceolata,* Jay (B), Randolph (D; B), Wayne (B). *F. quadrangulata,* Fayette (B). *Gentiana procera,* Randolph (B).

Apocynum cannabinum, Hancock (B), Huntington (Hu). *A. c.* v. *pubescens,* Delaware (B), Marion (B), Randolph (B). *A. sibiricum,* Randolph (B). *Acerates hirtella,* Gibson (D). *Asclepias syriaca,* Delaware (B), Fayette (B), Randolph (B). *A. tuberosa,* Delaware (B). *Cuscuta gronovii,* Randolph (B). *Convolvulus arvensis,* Delaware (B), Huntington (Hu). *C. sepium,* Huntington (Hu). *C. s.* v. *fraterniflorus,* Marion (B). *Ipomoea hederacea,* Randolph (D). *I. pandurata,* Delaware (B). *Phlox maculata,* Randolph (D, B). *Polemonium reptans,* Fayette (B). *Hydrophyllum macrophyllum,* Fayette (B). *Lappula echinata,* Marion (B). *Hackelia virginiana,* Randolph (B). *Verbena bracteata,* Clark (Mi), LaPorte (Mo). *V. canadensis,* Clark (Mi), Putnam (DP). XV. *engelmannii,* Cass (B), Hancock (B). *V. hastata,* Delaware (B), Huntington (Hu), Randolph (D). **XV. illicita Moldenke,** Rev. Sudam. Bot. 4: 18. 1937. Tippecanoe (P). Collected by H. B. Dorner. **XV. rydbergii** Moldenke, Rev. Sudam. Bot. 4: 19. 1937. Washington (D, NY). Collected by Charles C. Deam. *V. simplex,* Jackson (D), Lake (NY), Marion (D), Vermillion (D), White (P). *V. stricta,* Clay (D), Daviess (Fl), Delaware (B), Lake (G, NY), Steuben (D). *V. urticaefolia,* Adams (D), Franklin (D, DP), Huntington (Hu), Jay (B), Lake (G), Marion (B, Mi), Putnam (DP), Randolph (B), Steuben (D NY). *V. u.* v. *leiocarpa,* Brown (B), Dearborn (B), Decatur (B), Greene (B), Hancock (B), Jefferson (B), Jennings (D), Monroe (B), Randolph (D, B), White (D). *Phyla lanceolata,* Jay (B), Union (DP).

Teucrium canadense v. *virginicum,* Delaware (B), Randolph (B). *T. occidentale* v. *boreale,* Delaware (B), Randolph (B). *Scutellaria lateriflora,* Hancock (B), Huntington (Hu), Randolph (B). *S. ovata* v. *versicolor,* Huntington (Hu). *S. parvula,* Hancock (B). *Agastache nepetoides,* Hancock (B), Huntington (Hu). *Nepeta cataria,* Jay (B). *Prunella vulgaris* v. *lanceolata,* Randolph (B). *Physostegia virginiana,* Randolph (B). *Stachys tenuifolia,* Randolph (B). *S. t.* v. *hispida,* Fulton (B), Lagrange (B), Randolph (D). *S. t.* v. **platyphylla** Fern. Rhodora 45: 468. 1944. Clay (B), Delaware (B), Elkhart (D), Marion (D), Randolph (D, B). Collected by Charles C. Deam and Ray C. Friesner. *Monarda fistulosa,* Fayette (B), Madison (B). *Blephilia hirsuta,* Ran-

dolph (D, B). *Hedeoma pulegioides*, Fayette (B), Randolph (B). *Pycnanthemum pilosum*, Delaware (B). *P. virginianum*, Randolph (D, B). *Lycopus americanus*, Hancock (B). *L. rubellus*, Hancock (B). *L. uniflorus*, Hancock (B). *Mentha arvensis*, Randolph (D, B). *M. spicata*, Hancock (B), Randolph (B). *Collinsonia canadensis*, Fayette (B).

Physalis subglabrata, Hancock (B). *Solanum carolinense*, Fayette (B). *Verbascum blattaria*, Huntington (Hu). *V. thapsus*, Fayette (B), Huntington (Hu). *Linaria vulgaris*, Fayette (B). *Chaenorrhinum minus*, Delaware (B), Fayette (B), Randolph (B). *Scrophularia marilandica*, Randolph (B). *Chelone glabra* v. *linifolia*, Randolph (D). *C. g.* v.*l.* f. *velutina*, Randolph (B). *Mimulus alatus*, Randolph (B). *M. ringens*, Delaware (B). *Leucospora multifida*, Fayette (B). *Lindernia dubia* v. *riparia*, Delaware (B). *Veronica anagallis-aquatica* f. *anagalliformis*, Delaware (B). *V. serpyllifolia* Huntington (Hu). *Veronicastrum virginicum*, Delaware (B). *Gerardia paupercula*, Randolph (B). *G. purpurea*, Randolph (B). *Pedicularis lanceolata*, Randolph (B).

Catalpa bignonioides, Putnam (DP). *Ruellia carolinensis*, Hancock (B). *Plantago rugelii*, Madison (B), Randolph (D, B). *Cephalanthus occidentalis*, Delaware (B), Randolph (B). *Galium asprellum*, Randolph (D). *G. concinnum*, Randolph (B). *G. obtusum*, Fayette (B). *Sambucus canadensis*, Delaware (B). *Viburnum dentatum* v. *deamii*, Randolph (B). *Triosteum aurantiacum*, Randolph (B). *T. perfoliatum*, Randolph (D, B). *Symphoricarpus orbiculatus*, Huntington (Hu). *Lonicera prolifera*, Randolph (B). *Dipsacus sylvester*, Randolph (B). *Echinocystis lobata*, Randolph (D, B). *Lobelia kalmii*, Randolph (B). *L. spicata* v. *originalis*, Hancock (B).

Vernonia altissima, Randolph (B). *Eupatorium perfoliatum*, Delaware (B), Hancock (B), Randolph (D, B). *E. purpureum*, Randolph (B). *Liatris spicata*, *Randolph* (B). *Solidago altiissma*, Randolph (B). *S. canadensis* v. *gilvocanescens*, Wayne (B). *S. gigantea*, Hancock (B). *S. graminifolia* v. *nuttallii*, Huntington (Hu), Randolph (D, B). *S. juncea*, Delaware (B). *S. latifolia*, Fayette (B). *S. nemoralis*, Huntington (Hu). *S. patula*, Randolph (B). *S. riddellii*, Randolph (B). *S. rigida*, Delaware (B). *S. uniligulata*, Randolph (B). *Aster interior*, Newton (D). *A. novaeangliae*, Delaware (B). *A. pilosus*, Delaware (B), Huntington (Hu), Lagrange (D). *A. praealtus* v. *angustior*, Randolph (B). *A. sagittifolius*, Delaware (B). *A. umbellatus*, Randolph (B).

Erigeron annuus, Huntington (Hu), Randolph (B). *E. canadensis*, Delaware (B), Huntington (Hu). *Gnaphalium obtusifolium*, Gibson (Mo), Huntington (Hu), Madison (B). *Silphium integrifolium*, Delaware (B). *S. terebinthinaceum*, Madison (B), Randolph (D, B). *Ambrosia elatior*, Randolph (B). *A. trifida*, Hancock (B), Randolph (B). *Heliopsis helianthoides*, Randolph (B, D). *Eclipta alba*, Jay (B). *Rudbeckia deamii*, Randolph (B, D, G, N, NY). *R. hirta*, Fayette (B), Randolph (D, B). *R. laciniata*, Huntington (Hu). *R. triloba*, Huntington (Hu), Randolph (D). *Ratibida pinnata*, Delaware (B), Randolph

(B). *Helianthus giganteus,* Randolph (B). *H. petiolaris,* Marion (B). *H. rigidus,* Jay (B). *Actinomeris alternifolia,* Wayne (B). *Bidens connata* v. *pinnata,* Randolph (B). *B. coronata,* Randolph (D, B). *B. discoidea,* Randolph (D). *B. frondosa,* Delaware (B), Huntington (Hu).

Helenium autumnale, Delaware (B). *H. autumnale* v. **canaliculatum** (Lam.) T. & G. Rhodora 45: 485-495. 1943. Starke (D). Collected by Charles C. Deam. *H. a.* v. **parviflorum** (Nutt.) Fern. Rhodora 45: 485. 1943. Boone (B), Carroll (D), Cass (D, B), Clay (B), Crawford (D), Dubois (D, B), Floyd (D), Greene (D), Harrison (D), Hendricks (B), Howard (B), Madison (D, B), Martin (D), Newton (D), Owen (D), Pike (B), Randolph (B), Ripley (B), Shelby (B), Spencer (D), Starke (B), Sullivan (B), Tipton (D), Vigo (D), Washington (B), White (D, B), Whitley (D). *Anthemis cotula,* Randolph (B). *Achillea millefolium,* Delaware (B), Fayette (B). *Cacalia tuberosa,* Randolph (D, B). *Senecio aureus* v. **aquilonius** Fern. Rhodora 45: 495. Huntington (D), LaPorte (G). Collected by Charles C. Deam. *S. a.* v. *gracilis,* Elkhart (D). *S. a.* v. **semicordatus** (Mack. & Bush.) Greenm. Rhodora 45: 495. Jennings (B), Lagrange (D), Wells (D). Collected by Charles C. Deam and Scott McCoy.

Arctium minus, Fayette (B), Hancock (B), Randolph (D). *Cirsium arvense,* Huntington (Hu). *C. discolor,* Randolph (D). *C. muticum,* Randolph (B). *C. vulgare,* Gibson (Mo). *Cichorium intybus,* Randolph (B). *Tragopogon dubius,* Jasper (DP), Lake (G), Newton (DP), Porter (G). *Lactuca biennis,* Randolph (D, B). *L. b.* f. *integrifolia,* Randolph (B). *L. canadensis* v. *typica,* Randolph (D). *L. floridana,* Randolph (B, D). *L. scariola,* Hancock (B). *Prenanthes crepidinea,* Clark (D). *P. racemosa,* Randolph (B).

Nomenclatorial Changes

The following changes in names of Indiana plants are considered by the committee to be likely of acceptance by taxonomists generally. Other published changes have recently appeared in the literature but are temporarily withheld from this list awaiting further evidence of their merit and likelihood of general acceptance.

Scirpus atrovirens Muhl. to
S. atrovirens Willd.
Rhodora 46: 336. 1944

Rhynchospora cymosa Ell. to
R. globularis (Chapm.) Sm. var. **recognita** Fern.
Rhodora 46: 245-246. 1944

Rhynchospora glomerata var. minor Britt. to
R. capitellata (Michx.) Vhal
Rhodora 46: 115-121. 1944

Rhynchospora glomerata var. minor f. discutiens (Clarke) Fern. to
R. capitellata f. discutiens (Clarke) Gale
Rhodora 46: 119-121. 1944

Tradescantia canaliculatum Raf. to
T. **ohioensis** Raf.
Rhodora 46: 310-311. 1944

Luzula carolinae var. saltuensis (Fern.) Fern. to
L. **acuminata** Raf.
Rhodora 46: 4. 1944

Polygonatum commutatum f. ramosum McGivney to
P. **biflorum f. ramosum** (McGivney) Fern.
Rhodora 46: 12. 1944

Trillium gleasoni Fern. to
T. **flexipes** Raf.
Rhodora 46: 16-17. 1944

Trillium gleasoni f. walpolei (Farw.) Deam to
T. **flexipes f. walpolei** (Farw.) Fern.
Rhodora 46: 17. 1944

Smilax bona-nox L. to
S. **bona-nox** var. **hederaefolia** (Beyrich) Fern.
Rhodora 46: 36-38. 1944

Ludwigia alternifolia L. to
L. **alternifolia** var. **typica** Munz
Bull. Torr. Bot. Cl. 71: 158-159. 1944

Ludwigia alternifolia L. add
L. **alternifolia** var. **pubescens** Palmer & Steyermark
Bull. Torr. Bot. Cl. 71: 159. 1944

Ludwigia glandulosa Walt. to
L. **glandulosa** var. **typica** Munz
Bull. Torr. Bot. Cl. 71: 164. 1944

Ludwigia sphaerocarpa var. deamii Fern. & Grisc. to
L. **sphaerocarpa** var. **jungens** Fern. & Grisc.
Bull. Torr. Bot. Cl. 71: 161. 1944

Epilobium densum Raf. to
E. **rosmarinifolium** Pursh
Rhodora 46: 378. 1944

Stachys hispida Pursh to
S. **tenuifolia** var. **hispida** (Pursh) Fern.
Rhodora 45: 469-470. 1943

Stachys tenuifolia Willd. add
S. **tenuifolia** var. **platyphylla** Fern.
Rhodora 45: 468-469. 1943

Lycopus sessilifolius Gray to
L. **amplectens** Raf.
Rhodora 46: 56-57. 1944

Helenium autumnale L. add
H. autumnale var. parviflorum (Nutt.) Fern. and
H. autumnale var. canaliculatum (Lam.) T. & G.
Rhodora 45: 490-493. 1943.

Senecio aureus L. to
S. aureus var. intercursus Fern.
Rhodora 45: 499. 1943.

Senecio aureus L. add
S. aureus var. aquilonius Fern. and
S. aureus var. semicordatus (Mack. & Bush) Greenm.
Rhodora 45: 500-501. 1943

Cirsium virginianum (L.) Michx. to
C. flaccidum Small
Rhodora 45: 509-510. 1943

Deletions

The following deletion should be made from the previous report. *Panicum addisoni*: delete from 1941 report for LaPorte County.

State Flora Committee:
CHARLES C. DEAM, *Chairman*
RALPH KRIEBEL
T. G. YUNCKER
RAY C. FRIESNER, *Secretary*

CHEMISTRY

Chairman: F. B. WADE, Shortridge High School, Indianapolis

C. W. Holl, Manchester College, was elected chairman of the section for 1945.

Sweet white potatoes. W. E. THRUN and ELSIE REESE, Valparaiso University.—Katahdin potatoes stored in a dugout became sweet to the taste after the storage temperature in the presence of a farm lantern had become low enough to cause frost on the walls. Aqueous and 95 per cent alcohol extracts, the latter after evaporation to dryness and dissolving residue in water, showed definite reduction in Benedict's solution and positive reactions with Seliwanoff's reagent and definite levo-rotation, thus presumptively indicating the presence of fructose. Estimations of fructose were made colorimetrically after extracting the colored compound resulting from the Seliwanoff reaction into isoamyl alcohol. Two samples showed 4.0 per cent and 2.3 per cent, while polariscopic readings of the same 95 per cent alcohol extracts of thin slices indicated 1.5 per cent and 1.0 per cent respectively. The discrepancy is probably due to the presence of sucrose and glucose. Denny and Thornton, who have made low temperature storage investigations on potatoes at the Boyce Thompson Institute, mention the presence of sucrose and reducing sugars, but do not report comparatively high fructose content. It can then be presumed that the unsaturated gases emanating from the kerosene lantern were responsible for the abnormal fructose content of the potatoes. The sweet potatoes lost their sweet taste after storage at room temperature for a week, and an alcoholic extract of them showed dextro-rotation.

The Reaction of Polyanhydrides with Thiophene

JOHN H. BILLMAN and FRANK H. TRAVIS, Indiana University

It was first shown by Steinkopf (1) and later confirmed by Tainter (2) and Barger (3) that it is possible to substitute the thiophene ring for a phenyl group, in a pharmacologically active compound, and obtain a compound of approximately equal activity. In no instance, however, did these workers find a thiophene-containing compound with an activity greater than the corresponding benzene isologue. Accordingly, it was decided to prepare some other thiophene-containing compounds to throw further light on this interesting observation.

Since acetophenone possesses a marked hypnotic activity, it was felt that the preparation of its thiophene isologue, acetothienone, would be an excellent starting point for this investigation. In addition propiothienone and butyrothienone were also synthesized (4) in order to see what effect an increase in the length of the carbon chain would have on hypnotic activity.

In contrast to the earlier observation made by Steinkopf, that thiophene isologues are analogous in physiological activity to the benzene derivatives, these three ketones proved to be quite toxic and were not hypnotics.

Because of this anomalous result, an attempt was made to synthesize some diketones of the type $C_4H_3SCO(CH_2)_x\ COC_4H_3S$ to see if they might possess anticonvulsant activity. As a basis for the preparation of these diketones reference was made to the work of Hill (5) who reports that polyadipic and polysebacic anhydrides react with benzene, in the presence of aluminum chloride, to give keto acids and diketones of the desired general structure. The only other reference found pertaining to the utilization of a polyanhydride in the Friedel-Crafts' reaction is in an article by Plant and Tomlinson (6) in which they report the formation of δ-anisoylvaleric acid and α, δ-dianisoylbutane from polyadipic anhydride and anisole. When phenetole was used they obtained δ-phenetoylvaleric acid and α, δ-diphenetoylbutane.

We have found that thiophene would react similarly with polyanhydrides but that it was essential to use stannic chloride instead of aluminum chloride to prevent excessive polymerization of the thiophene. The reaction may be shown in equation form by using sebacic anhydride as a typical example:

$$C_4H_4S + (CO(CH_2)_8CO_2)_x\ (+SCl_4) = C_4H_3SCO(CH_2)_8COC_4H_3S + C_4H_3SCO(CH_2)_8COOH$$

The polyanhydrides used were adipic, suberic, azelaic and sebacic. These were prepared by refluxing the corresponding dibasic acid with acetic anhydride and then removing by distillation under reduced pres-

sure the acetic acid, formed during the reaction, along with the excess acetic anhydride.

In addition to the above polyanhydrides, one cyclic anhydride, succinic anhydride, was allowed to react with thiophene (7). In the reactions involving succinic anhydride and polyadipic anhydride, only the keto acid could be isolated whereas with the other polyanhydrides it was possible to isolate the diketone as well as the keto acid.

The diketones and keto acids which have been tested show no anticonvulsant action except in the case of β-(α-thenoyl) propionic acid which was found to be approximately fifteen per cent as active as diphenylhydantoin.

The authors wish to thank Eli Lilly and Company and Dr. E. E. Swanson, of the same company, for running the pharmacological tests on these compounds.

Experimental

Preparation of Polyanhydrides.—The polyanhydrides were prepared by a procedure similar to that used for the synthesis of azelaic polyanhydride.

Azelaic Polyanhydride.—In a 250 ml. flask fitted with a reflux condenser were placed 37.6 g. of azelaic acid and 90 ml. of acetic anhydride. The oil-bath surrounding the reaction flask was heated to 170° and kept at that temperature for eight hours and then cooled. The upright condenser was then replaced by a condenser for downward distillation and the system evacuated by a water pump. The temperature of the bath was gradually raised to 120° C. and kept at that temperature until no more acetic anhydride came over. The azelaic polyanhydride remaining in the flask was cooled and then dissolved in 100 ml. of dry benzene.

The Reaction of Polyanhydrides with Thiophene.—The diketones and keto acids in Table I were prepared from thiophene and the proper polyanhydride in the presence of anhydrous stannic chloride. The procedure which follows is similar to that used for the synthesis of the other diketones and keto acids.

1,7 Di(α-thenoyl)heptane and 8(α-thenoyl)octanoic acid.—In a 500 ml. three-neck flask fitted with a mechanical stirrer, condenser, and a thistle tube with a stopper holding a burette, were placed 16.8 g. of thiophene and the benzene solution containing the azelaic polyanhydride. The mixture was cooled to 0° and 46.8 ml. of anhydrous stannic chloride dropped in over a period of one hour. The mixture was allowed to warm up to room temperature and stirred for an additional hour. The reaction mixture was cooled with ice and treated with 300 ml. of 10% hydrochloric acid. The benzene layer was separated from the acid solution and then extracted several times with a 5% sodium hydroxide solution. After washing with water the benzene solution was evaporated in vacuo ,to remove all of the benzene. The oily residue, on cooling, solidified to give light yellow crystals. Recrystallization from alcohol gave 8.7 g. (27% yield) of 1,7 di-(α-thenoyl) heptane melting at 66.5-67°.

Table I

Compounds prepared	M. P. °C.	Yield %	Carbon % Calcd.	Carbon % Found	Hydrogen % Calcd.	Hydrogen % Found
Keto Acids						
3-(α-Thenoyl) propanoic acid*	119-120	58.5				
5-(α-Thenoyl) pentanoic acid	76.5-77	3.8	56.50	56.73	5.65	5.88
7-(α-Thenoyl) heptanoic acid†			59.17	59.91	6.63	6.84
8-(α-Thenoyl) octanoic acid	63-65	24.5	61.41	61.40	7.08	6.90
9-(α-Thenoyl) nonanoic acid	54.5-55	8.3	62.68	62.60	7.51	7.66
Diketones						
1,6 Di(α-thenoyl) hexane	72.5-73	29.8	62.74	62.87	5.89	5.94
1,7 Di(α-thenoyl) heptane	66.5-67	27.0	63.75	64.25	6.25	5.98
1,8 Di(α-thenoyl) octane	66.5-67	21.2	64.67	64.64	6.69	6.79

* Previously prepared by Fieser (7).

† This keto acid melted in the region of room temperature and apeared to decompose during purification and on standing.

The alkaline solution was acidified with 10% hydrochloric acid and extracted with several 50 ml. portions of ether. The ether extract was evaporated in vacuo until all of the ether was removed. The remaining oil solidified when cooled and melted at 50-60°. Recrystallization from petroleum ether gave 6.3 g. (24.5% yield) of 8(α-thenoyl)octanoic acid melting at 63-65°.

Summary

1. It has been shown that suberic, azelaic, and sebacic polyanhydrides will react with thiophene in the presence of stannic chloride to give diketones and keto acids. Polyadipic anhydride gave only the keto acid.

2. None of the new ketones or keto acids tested for anticonvulsant activity were found to be active.

3. The 3-(α-thenoyl)propanoic acid, prepared from thiophene and succinic anhydride, was found to be approximately 15 per cent as active as diphenylhydantoin.

Bibliography

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4. Raczynski, 1939. Senior Thesis, University of Illinois.
5. Hill, 1932. J. Am. Chem. Soc., **54**:4105-4106.
6. Plant and Tomlinson, 1935. J. Chem. Soc., 1092-1094.
7. Fieser and Kennelly, 1935. J. Am. Chem. Soc., **57**:1611-1616.

A Rapid Method for the Qualitative Detection of Lead in the Presence of Bismuth, Copper and Cadmium

E. St. Clair Gantz, Purdue University

The classical method for the separation and detection of lead in qualitative analysis is time consuming and is not "foolproof" for inexperienced analysts. Practically all standard qualitative analysis books describe this method, which is as follows: The sulfides of lead, bismuth, copper and cadmium are dissolved in nitric acid; concentrated sulfuric acid is added and the solution evaporated until fumes of sulfur trioxide appear; the solution is diluted with cold water and the lead sulfate removed by filtration; the lead sulfate is dissolved in ammonium acetate solution and the lead detected by the addition of a chromate salt which precipitates lead chromate. This method is subject to the following criticisms:

1. The inexperienced analyst mistakes steam for sulfur trioxide fumes. Consequently all nitric acid is not removed and some lead is lost due to the increased solubility of lead sulfate in the more acidic solution.

2. The solution is evaporated too far and the precipitate is a mixture of lead sulfate and basic bismuth sulfate. If lead is absent, the bismuth will give a false test for lead. Thus, the presence of lead must be confirmed by treatment with sodium hydroxide which would dissolve any lead chromate present. The bismuth salt is insoluble in sodium hydroxide. Consequently, acidification with acetic acid will reprecipitate lead chromate if it is present.

3. The whole procedure takes too much time.

The proposed method is as follows. Add ammonia solution to the nitric acid solution of the sulfides; this will precipitate basic salts of lead and bismuth; filter; then dissolve the lead salt with ammonium acetate solution; acetic acid is added to produce a pH of about 3 and then upon the addition of potassium chromate lead chromate will precipitate. The basic bismuth salt is slightly soluble in the ammonium actetate solution but the addition of acetic acid prevents the precipitation of bismuth chromate.

In tests with lead absent and as much as 500 mg. of bismuth in the sample no precipitate was obtained upon addition of potassium chromate when the ammonium acetate solution had been lowered in pH by the addition of acetic acid.

This procedure has been used for two terms in classes of about 100 each with good results. Most of the unknowns contain from 50 to 100 mg. of each ion.

The actual details of the procedure are as follows: Place the nitric acid solution which may contain lead, bismuth, copper and cadmium in a

100 ml. beaker. Add 4M ammonia solution until just alkaline and then add 8 ml. in excess and filter. Save the filtrate for copper and cadmium tests. A white gelatinous precipitate may be basic salts of lead and bismuth. Wash the residue on the filter paper with two 10 ml. portions of distilled water which are discarded. Pour 10 ml. of warm 3M ammonium acetate solution over the residue on the filter paper at least three times catching the solution in a test tube. Add 4 ml. of 4M acetic acid, which will produce a pH of about 3, and 1 ml. of 1.5M potassium chromate solution to the ammonium acetate solution. A bright yellow precipitate, forming immediately, indicates the presence of lead. The presence of bismuth is determined by pouring a sodium stannite solution over the filter paper after the lead has been extracted. The copper and cadmium tests can be made in any of several ways.

Summary

A new method for the detection of lead is proposed whereby lead and bismuth are precipitated from nitric acid solution by the addition of ammonia solution. The lead is extracted from most of the bismuth by the use of ammonium acetate. The presence of lead is determined by the addition of potassium chromate solution to the ammonium acetate extract after the pH is lowered by the addition of acetic acid, which prevents the precipitation of any bismuth chromate. This procedure is much more rapid than the one commonly used and is also less subject to error in beginners' hands.

Oxides of Nitrogen in Ozonized Air

C. E. KASLOW and R. DALE STAYNER, Indiana University

There is very little agreement among the numerous papers which have been published on the content of oxides of nitrogen in ozonized air. The divergence in results might be attributed to either the method of analysis or the performance of the individual ozone generator. There are many methods for the determination of nitric acid and the oxides of nitrogen but the common method for analysis of ozone involves the reaction between potassium iodide and a measured volume of ozonized oxygen. The iodine liberated by the ozone is determined by the standard thiosulfate method. The method of analysis has been criticized on the basis that oxides of nitrogen which are present in ozonized air also liberate iodine.

However, it has been established that nitric oxide and nitrogen dioxide do not exist as such in the presence of ozone but are oxidized to nitric anhydride (1, 2). Furthermore, it has been established by many investigators (3, 4, 5, 6) that pure, dilute nitric acid is not an oxidizing agent.

As much as 75 per cent of the oxidizing material in ozonized air is claimed by Thorpe (7) to be oxides of nitrogen. No method of analysis is given but in a later publication (8) the same author mentioned the use of diphenylbenzidine (9) as a colorimetric method for the determination of nitric acid. Ewell (10) has stated that only traces of nitric anhydride are present in ozonized air. In a recent publication, Watson (11) reported two laboratory type ozone generators which produced only 1 part of nitric anhydride to 2,580 and 30,150* parts of ozone, respectively. Gorodetzkii (12) has reported the formation of about 2 per cent of nitric anhydride in ozonized air. Briner and Papazian (13) found that commercial oxygen containing about 2.2 per cent nitrogen gave only a trace of nitric anhydride when ozonized. Calculated as nitric oxide, it amounted to about 0.00014 per cent of the volume of oxygen. The method of analysis consisted of the absorption of the nitric anhydride in a given volume of ozonized oxygen by means of dilute aqueous alkali, reduction of the nitrate to nitrite by zinc and the latter substance determined colorimetrically by the Griess-Ilosvay method.

The usefulness of ozonized air and the action of ozone on oxides of nitrogen as a method for fixation of nitrogen has been investigated (14, 15, 16) and found not feasible.

The most feasible method for the estimation of nitric anhydride seemed to be as nitric acid. The determination of nitric acid as nitron nitrate (17) has been established as a reliable method (18, 19). Schultz and Wulf (15), and Watson (11) have shown complete absorption of

* The value may have been a typographical error.

nitric anhydride in water and dilute aqueous alkali. However, the fog which is produced when ozonized air is bubbled into aqueous solutions has been shown by Anderegg and McEachron (20) to consist of nitric acid. Collection of a known volume of ozonized air and analysis of it for nitric acid would obviate the error which might occur from incomplete absorption if the gas was bubbled through water or aqueous alkali.

The ozone generator consisted of three Berthollet tubes connected in series. The apparatus was modeled after the ozone generator described by Smith (21) but with certain modifications (22).

Procedure

Ozonized air was swept through a dry 3-liter flask for two hours, then the stopcocks turned so as to by-pass the flask. Fifty ml. of 0.1 N sodium hydroxide solution was added to the flask by means of a dropping funnel which was attached to the flask by means of a ground glass joint. The flask was removed, capped and the solution agitated frequently. The solution was allowed to stand over night in the flask to insure complete absorption of the nitric anhydride vapor.

The contents of the flask were poured into a 500-ml. Erlenmeyer flask and the inside of the 3-liter flask washed with three 25-ml. portions of distilled water. The alkaline solution was heated at its boiling point for a few minutes to destroy the ozone. The hot solution was acidified with 5 ml. of glacial acetic acid and then 10 ml. of nitron acetate solution containing 0.33 g. of nitron was added. The solution was allowed to cool to room temperature and as the nitron nitrate crystals began to form, it was agitated frequently. The solution was placed in a refrigerator over night. The temperature in the refrigerator remained consistently at $8 \pm 1°$ C. The nitron nitrate was collected in a weighed Gootch crucible and dried to constant weight at 85-90° C. A correction was made for the solubility of nitron nitrate (23).

The volume of ozonized air was corrected to standard conditions and the percentage of nitric anhydride calculated from the weight of nitron nitrate.

Discussion

Nitric oxide and nitrogen dioxide are not completely absorbed in either an alkaline solution or in water and the aqueous solution will give a test for nitrite. To determine whether or not nitrous acid was formed, ozonized air was bubbled through water and the latter substance tested for nitrite. The presence of nitrous acid could not be detected when the sulfanilic acid alpha-naphthylamine test (24) was used. To further ascertain that the method of absorption was not at fault, an analysis was made in which the nitric anhydride was absorbed in dilute sulfuric acid containing hydrogen peroxide (25); the methods checked one another satisfactorily. It was also necessary to determine whether or not there was an accumulation of nitric anhydride in the flask. To do this, ozonized air was passed through the flask for six hours then the gaseous contents of the flask analysed for nitric anhydride. No accumula-

tion of nitric anhydride had occurred since the percentage was the same as in previous trials.

The effect of voltage and the rate of flow of air was studied. The data and results are given in Table I.

Table I

Det'n #	Rate l/hr.	Voltage, M.	Vol. of ozonized air, cor., ml.	Nitron Nitrate, g.	Per cent N_2O_5 Vol.	Per cent N_2O_5 Wt.
1	22	10	3010	0.1393	0.142	0.530
2	22	10	3105	0.1434	0.134	0.500
3	22	12	3012	0.1818	0.180	0.671
4	22	10	3053	0.1412	0.139	0.518
5	22	8	3022	0.1019	0.101	0.376
6	22	6	2971	0.0462	0.046	0.172
7	18	10	3042	0.1723	0.169	0.630
8	15	10	3089	0.1958	0.190	0.708

As shown in Table I, at 10,000 volts and a rate of 22 liters per hour the nitric anhydride in the ozonized air averaged about 0.52 per cent by weight. The amount was increased at 12,000 volts and was reduced to 0.17 per cent at 6,000 volts. A decrease in the rate of flow of the air resulted in an increase in the percentage of nitric anhydride. This effect of the rate of flow has been observed by Schultz and Wulf (15).

A séries of determinations were made to ascertain the effect of nitric anhydride on the sodium thiosulfate titration. Ozonized air was bubbled through a 5 per cent potassium iodide solution at a rate of 8.9 liters per hour for three-minute intervals and the iodine determined by the usual method, using 0.1161 molar sodium thiosulfate solution. The apparatus was arranged so that the ozonized air could be either passed through a trap cooled with a mixture of ether and solid carbon dioxide or by-passed directly to the potassium iodide solution. The temperature of the cooling bath was —68° C. Much of the nitric anhydride was removed by the freezing process since only a small amount of fog was formed above the potassium iodide solution and its accumulation was also visible in the trap. The volume of the sodium thiosulfate solution used for each determination is shown in Table II.

Table II

Det'n #	Thiosulfate ml.	Det'n #	Thiosulfate ml.	Det'n #	Thiosulfate ml.
1	8.45	5	8.73	9	8.75
2	8.60	6	8.76	10	8.73
3	8.73	7	8.77	11	8.63
4	8.53	8	8.50		

In determinations 1,2,6,7,10 and 11 the ozonized air was not passed through trap. The average of these values is 8.66 ml. The average of the determinations in which ozonized air was passed through the trap cooled to —68° C. was 8.65 ml. This would indicate that at lower concentrations of nitric anhydride in ozonized air, it does not interfere with the determination of ozone when the potassium iodide method is used.

To accumulate considerable nitric anhydride, ozonized air was passed through the cooled trap for approximately 1.5 hours, then the trap was by-passed and the cooling bath removed. After the trap had warmed in the air for about five minutes, the stream of ozonized air was directed through it at the same rate as used previously. The nitric anhydride was removed in about four minutes but the ozonized air was allowed to continue to pass for exactly five minutes. It required 16.88 ml. of the sodium thiosulfate solution for titration of the iodine which had been liberated from the potassium iodide. On the basis of the previous results, it should have required 14.42 ml. of the sodium thiosulfate solution; this would indicate that a high concentration of nitric anhydride does interfere with the determination of ozone.

Operating at 10,000 volts, the ozonized air from the ozone generator contained 2-3 per cent ozone by volume, depending upon the rate of flow of air.

Summary

1. The concentration of nitric anhydride in ozonized air was determined by hydrolysis of the anhydride to nitric acid which was determined by the nitron method.

2. The amount of nitric anhydride in ozonized air is dependent on the voltage and rate of flow of air.

3. The nitric anhydride in ozonized air does not interfere with the determination of ozone by the potassium iodide sodium thiosulfate method.

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Inhibited Acids for Recovering Tin from Tin Cans

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If an inhibited acid would dissolve tin and not iron, a method of treating scrap tin cans would be possible. Such an inhibitor must not reduce the activity of the acid for the tin itself. These experiments tested out the possibility of such a detinning method.

There are many inhibitors, usually organic, which will reduce the activity of acids, e.g., sulfuric acid, upon metallic iron. These inhibitors are widely used in the acids for the pickling of iron to remove oxide and scale whose solubility in acids is not affected by the inhibitors. It is thus apparent that much less acid will be required and much less iron will be dissolved and lost during the time required to dissolve the oxide and scale, if an inhibitor is used.

Discussion of Inhibitors

1. Arsenious oxide is very effective even in hydrochloric acid which is much more difficult to inhibit than is sulfuric acid. There is always an objection to the use of a poisonous substance. With arsenic there is the possibility of the evolution of the very toxic substance, arsine.

2. Formaldehyde is very convenient for laboratory use on account of its cleanness and its ready availability. It is not especially effective.

3. Quinoline ethiodide is claimed to be especially active, but it is expensive.

4. Glycerine foots is the residue remaining in the stills after glycerine has been recovered by distillation in soap making. It contains some glycerine, large quantities of sodium chloride and many other things in small quantities. In a previous research in this laboratory, glycerine foots was found to be a good brightening agent in cadmium electroplating baths.

Glycerine foots is available in large quantities and, so far as the author knows, no very extensive use for it have been found.

Experimental

These experiments were all run at room temperature with 2 N. solutions of hydrochloric and of sulfuric acid. Square pieces of ordinary tin cans 1½ inches on a side were used. These pieces were bent into S-shapes so that the acid could attack both sides. Fifty ml. of acid was used in each experiment.

The loss in weight in mgm. of each piece of tin can (original weight of each was near 3.5 gm.) after 24 hours in the acids was:

	No Inhibitor	0.5 gm. As_2O_3	2 ml. HCHO	1 gm. quinoline ethiodide	3 gm. glycerine foots
HCl	337.0	99.	019.	28.2	10.1
H_2SO_4	16.9	17.4	008.9	9.0	9.7

After 18 days, the losses were

HCl	. .	398.8	. . .	.	. . .
H_2SO_4	. . .	046.9	425.9	163.1	94.8

Where there are blank places in the table, the metal pieces were too completely dissolved to be handled and weighed. These data indicate that the tin coating itself is rather resistant to the acids for a short period of time and that most of the inhibitors give good protection even for 18 days in the sulfuric acid. Arsenic was the only inhibitor that gave much protection in hydrochloric acid for 18 days. An explanation for the poor showing of the formaldehyde in the 18 day run is that it was destroyed by oxidation or lost by evaporation.

Pieces of the same can, after removing the tin with acid, were tried in the 2 N. acids to see the action on the iron itself.

Loss in 24 hours

	No Inhibitor	0.5 gm. As_2O_3	2 ml. HCHO	0.5 gm. quinoline ethiodide	3 gm. glycerine foots
HCl	. .	11.4 mg.	7.7 mg.	19.2 mg.	301.0 mg.
H_2SO_4	. .	8.3	45.5	9.5	125.1

Loss after 14 days

HCl	. .	111.6	164.1	. . .	Note 1
H_2SO_4	. . .	85.8	930.9	1104.3	Note 1

Note 1. Not tried.

Conclusions

1. These experiments indicated that inhibitors would not solve the problem of recovering tin from tin cans because no inhibitor sufficiently prevented acids from dissolving iron.

2. The tin coating, itself, was much less soluble in the acids than is the iron.

The Preparation and Properties of Certain Ether Derivaties of Starch†

DAVID RANKIN with ED. F. DEGERING, Purdue University

Because of its cheapness and commercial availability starch has been employed extensively in the past for uses that require a relatively small change in the starch molecule. It is for these reasons that starch is now being examined for possible transformation into compounds in which a major change in its properties may be effected.

The present work is limited to the preparation and examination of some of the lower alkyl derivatives of starch. It is hoped that the properties of these alkyl derivatives of starch will make them of value in the arts.

Much work has been done on the methyl derivatives of starch for this has been a favorite tool in the hands of those men interested in the molecular structure of starch (1) (2) (3) (4). A few references and patents are available for the ethyl derivative but propyl and butyl derivaties of starch are merely mentioned in the literature (5) (6).

Experimental

Adequate experimental data for the methyl derivatives of starch may be found readily in the literature (1). The original patent of Lilienfeld (6) on the ethyl derivative of starch is satisfactory for use in the preparation of this product.

The propyl derivative of starch is only mentioned in the literature (5). It is, however, readily prepared by our procedure. Its properties are of interest because of its low solubility in water. A procedure developed for obtaining this derivative is:

Thirty grams of corn starch (10-15% moisture), 60 g. of solid sodium hydroxide, 450 g. of a 40% solution of sodium hydroxide, and 277 g. of *n*-propyl chloride are agitated in a stirred, heated autoclave for 24 hours at a temperature of 135-140°C. A grey solid is obtained on steam distillation of the reaction product. This solid is readily purified by dissolving in glacial acetic acid, filtering, and precipitating with water, or by pouring the acetic acid solution into violently agitated water. The white product, which floats to the surface, is filtered, washed with sodium carbonate to remove acetic acid, and then thoroughly washed with distilled water. The yield of the air-dried product is about 30 grams.

No adequate data are available in the literature for the preparation of the butyl derivative of starch. It was prepared in this laboratory by the following procedure.

† Based upon a thesis submitted by David Rankin to the Faculty of Purdue University in partial fulfillment of the requirements for the Degree of Doctor of Philosophy, June, 1942.

Fifteen grams of corn starch, 250 g. of 40% sodium hydroxide, and 160 g. of *n*-butyl chloride are rocked in a heated bomb for 24 hours at 165-170°C. The product is steam distilled to remove butyl chloride, butyl ether, and butyl alcohol. After cooling, a compact, brittle solid is obtained which may be purified by use of glacial acetic acid (cf. propyl derivative). The product is a white, fluffy powder which is not plasticized by acetic acid during the purification process. About 18.4 g. of the alkylated product is obtained. Higher temperatures or higher alkali concentrations must be avoided to prevent the formation of butyl ether which is tenaciously retained by the alkylated product.

Physical Examination

The methyl derivative of starch is water soluble and therefore must meet the competition of cheaper starch products. The ethyl derivative of starch can be made both as water soluble and insoluble derivatives. One alkyl group per glucose residue produces water solubility, whereas two ethyl groups gives a water insoluble product. The latter product is more soluble in organic solvents.

The propyl derivative of starch is definitely water insoluble when two propyl groups per glucose unit have been introduced into the molecule. The butyl derivative of starch is even more like the non-polar type of organic compound. Solubility characteristics can be obtained from Table I in which S indicates soluble, I indicates insoluble, and PS indicates partially soluble.

Table I. Solubility of Alkyl Starches

Solvent	Ethyl Derivative	Propyl Derivative	Butyl Derivative
Acetone	S	S	S
Toluene	S	S	S
Amyl Acetate	S	S	S
Butanol	S	S	S
Petroleum Ether	I	PS	PS
Tetrachloroethane	.	S	S
Ethyl Alcohol (95)	S	S	PS

These alkylated derivatives of starch are compatible with commonly used plasticizers such as dibutyl phthalate, tributyl phosphate, ethox, flexol, tributyl citrate, and hercolyn.

Because of the nature of the compounds no accurate melting point can be obtained for these derivatives. The observable physical change can be described as a shrinking or softening.

Table II. Softening Points of Alkyl Starches

Ethyl Derivative of Starch	140-145°C. (uncorr.)
Propyl Derivative of Starch	105-110°C. "
Butyl Derivative of Starch	73- 76°C. "

As might be expected, the specific gravity of the alkyl ethers of starch vary with the length of the alkyl group introduced. The products have about the same specific gravity as the corresponding alkyl ethers of cellulose and hence have a large spreading power as against the more dense materials such as the acetate or nitrate of starch or cellulose.

Table III. Specific Gravity of Alkyl Starches

Product	Specific Gravity	Temperature
Ethyl Derivative of Starch	1.14	27°C.
Propyl Derivative of Starch	1.05	28°C.
Butyl Derivative of Starch*	.88	28°C.

* Kerosene used as the liquid.

The viscosity of these alkylated products varies inversely as the chain length. The higher alkyl derivatives require more drastic means in their preparation and this is reflected in the degradation which contributes to the low viscosity. Table IV contains the viscosity in centipoises of these derivatives as determined in a 5% toluene solution using an Ostwald viscosimeter.

Table IV. Viscosity of Alkyl Starches

Product	Time in Seconds	Viscosity in Centipoises
Ethyl Derivative of Starch	586	2.92
Propyl Derivative of Starch	390	1.97
Butyl Derivative of Starch	210	1.06

Summary

The lower alkyl derivatives of starch have been prepared and characterized. These derivatives at present are costly to make and hence their use must be justified. As the character of these compounds becomes more widely known and better procedures for their production developed, uses for them will justify the volume of production necessary for commercial practicability.

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Quantitative Determination of Non-Aminoid Nitrogen in Aliphatic and Aromatic Compounds

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It became apparent during the course of investigation of the titanium trichloride-ferric chloride titrimetric method of analysis of nitro-aliphatic compounds (1), that the method was unsuitable for a rapid, accurate, and easily performed analysis.

By combining the essential feature of the titrimetric method, namely the reduction of the nitro group with titanium trichloride, with the Kjeldahl digestion of the amine hydrochloride, it was found possible to recover quantitatively the nitrogen of the nitro group in the form of ammonia. A test of the method with compounds of the aromatic and aliphatic series with groups such as nitro, azo, diazo, and other non-aminoid groups present gave excellent and rapid results.

Apparatus: A simplified and inexpensive Kjeldahl distillation-aeration apparatus designed some years ago by Dr. R. C. Corley, Purdue University, containing the accumulated improvements of graduate students in the department, (See Fig. 1) was used.

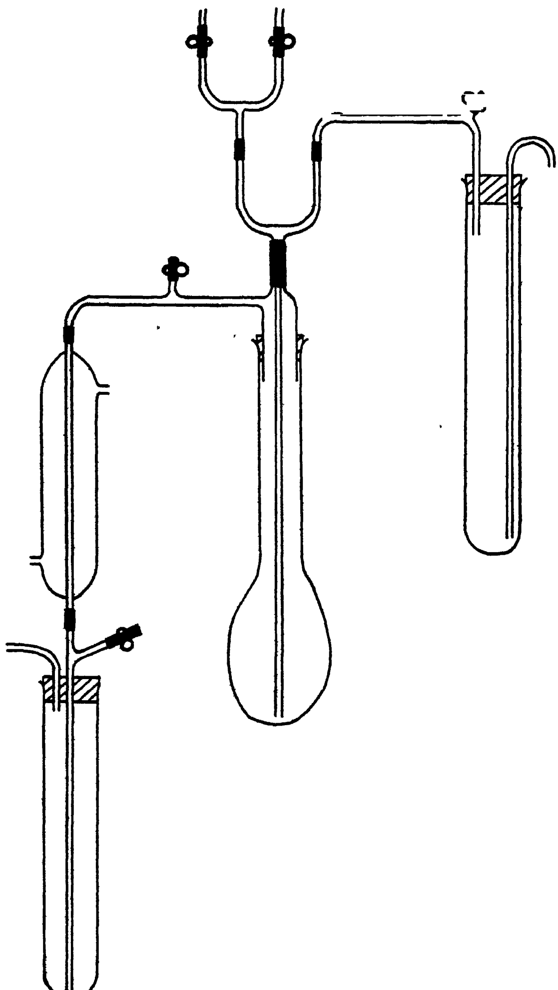
Reagents: All reagents are of analytical grade.

Sodium hydroxide—50% solution.
Boric acid—2% solution.
Standard sulfuric acid—.0100 N solution.
Concentrated sulfuric acid for digestion solution.
Cupric sulfate (anhydrous), Mercuric Oxide, and Potassium Sulfate.
Methyl-red and brom-cresol-green—0.1% alcoholic solution mixed in the ratio of 1:5 (Ma & Zuazaga).
Titanium trichloride—20% solution in concentrated hydrochloric acid.

Method: Reduction and digestion of sample: The compound is weighed by difference in a small ampule made from a two inch test tube. The ampule is placed into a 100 ml. Kjeldahl flask which contains approximately one ml. of a 20% titanium trichloride (in conc. HCl) solution and two ml. of 95% ethanol. If the compound is volatile, the Kjeldahl flask is stoppered and allowed to stand at room temperature for 5 to 10 minutes with occasional shaking. This step is not necessary for the non-volatile compounds. After standing, the stopper is removed and the sample slowly warmed to the boiling point and held there for two minutes. At this point, approximately 50 mg. each of HgO, $CuSO_4$, and K_2SO_4, plus 5 ml. of concentrated H_2SO_4 are added and the sample is digested on a sand bath until completely decomposed. Bumping is minimized by the addition of several small glass beads to the flask.

Distillation and Aeration: The digested sample is allowed to cool. The ampule is broken with a glass rod to prevent entrapment of ammonia

and the rod and flask are rinsed with distilled H_2O. The Kjeldahl flask is then connected to the aeration apparatus and a rapid stream of air is drawn through for a minute to remove any SO_2 or SO_3 fumes that may be present in the flask. After the condenser is rinsed with distilled water, the boric acid tube containing 35 to 40 ml. of 2% boric acid is attached to the apparatus. The aeration is begun and the 50% NaOH



is allowed to enter the flask. When the contents become a brownish color, the addition of 50% NaOH is discontinued. The flask is then heated with a micro burner for 3 minutes. At the end of this time the ammonia is completely distilled from the flask and the boric acid tube is removed and suitably rinsed. The boric acid solution is then titrated with standard acid using the mixed indicator.

Discussion of Method: After the sulfuric acid is standardized by the usual Na_2CO_3 method, it is restandardized with $(NH_4)_2SO_4$ of known purity using the Kjeldahl procedure. This will automatically take care of the minute amount of NH_3 that may be present in any of the reagents used.

Essentially the boric acid method of Ma and Zuazaga is followed (5).

The method proved extremely valuable in the case of the compounds listed in Table II, most of which are unstable when heated and decompose between 30-40°C. Thus, the Dumas combustion method gave high results for nitrogen and carbon and hydrogen combustion gave low results for both carbon and hydrogen. These results were obtained because the compounds decomposed so rapidly in the combustion tube that complete oxidation of the breakdown products did not take place. Also the dextrose reduction method (2) could not be used for the compounds since the compounds could not be heated until after they were reduced.

Table I.

	Nitrogen, %		
	Calcd.	Found	
$CH_3CH_2NO_2$	18.66	18.62	18.65
$CH_3CH_2CH_2NO_2$	15.72	15.67	15.70
$(CH_3)_2C(NO_2)CH_2NH \cdot CH(CH_3)_2$	17.49	17.42	17.42
$CH_3CH_2CH(NO_2)CH(CH_3)CO_2(CH_2)_2CH_3$	6.93	6.99	6.95
Oxime*	20.26	20.28	20.27
$CH_3CH(NO_2)CH_2CH_2C{\equiv}N$	21.87	21.67	21.70
$C_5H_6NO_2$	11.38	11.30	11.33
Picrate derivative of an amine*	8.80	8.76	8.78

* New compounds.

Table II.*

Amine diazotized	Nitroamine coupled**	Nitrogen, % Calcd.	Found
Aniline	M	20.15	20.1
β-Naphthylamine	B	14.58	14.6
p-Aminobenzoic acid	M	17.40	17.3
p-Chloroaniline	B	15.18	15.3
p-Chloroaniline	M	17.90	17.6
o-Nitroaniline	M	21.65	21.6
m-Nitroaniline	M	21.65	21.4
p-Aminoazobenzene	M	22.0	22.4

* Compounds prepared and analyzed by Gerhard Van Biema, Purdue University, 1943.

** M = 1-N-morpholino-2-nitropropane.
B = 1-di-*n*-butylamino-2-nitrobutane.

The method is much superior to the titrametric determination as given by various investigators (1,3,4).

Conclusion. This is a rapid and accurate method for the determination of nitrogen in volatile aliphatic, unstable aromatic compounds, as well as stable aromatic non-aminoid compounds. Titanium trichloride proved to be an excellent reducing agent. Determinations are made on semi-micro scale using an efficient time saving aeration-distillation apparatus for the distillation of ammonia formed from the decomposed compound.

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The Vapor Pressure of Dimethylamine from 0 to 40° C.

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As part of a series of investigations of the properties of the simple aliphatic amines near room temperature (5, 6, 7), we have measured the vapor pressure of dimethylamine at several temperatures between 0 and 40° C.

Previous determinations of the vapor pressure of dimethylamine have been carried out by Berthoud (3), Simon and Huter (4), and by Aston, Eidinoff and Forster (1). Berthoud measured the vapor pressure of dimethylamine from 5° up to the critical temperature, 164.55°; however, he reports only two values below 40°. The other workers were mainly interested in values up to the normal boiling point, 6.88° C.

Experimental

Two series of measurements were made using a different sample of carefully purified dimethylamine for each series. The purification has been described previously (5). The amine was sealed in an all-glass apparatus, dried over solid potassium hydroxide, and desiccated by dissolving sodium fluorenone in it (2). The dry amine was then evaporated through a spray trap into another bulb and frozen with liquid air. The system was evacuated to 10^{-4} mm. or lower and the amine then allowed to melt. The freezing and melting process was repeated at low pressure until the amine had been reduced to about ⅔ of the original volume, to make sure that all dissolved gases had been removed.

The vapor pressure at the ice point was then taken. To check the absence of dissolved gases, the vapor was allowed to expand into a much larger volume, and the vapor pressure again measured. Finding the same value of the vapor pressure in the two cases was taken as sufficient proof of the purity of the sample.

The samples were transferred by vacuum distillation to an isotensiscope equipped with a magnetic stirrer which served to break the surface of the liquid about twice a second. The vapor pressure at the ice point was again measured and found to check the previous readings within a millimeter.

At each temperature care was taken to allow sufficient time for equilibrium to be established, as evidenced by a steady reading for at least half an hour while the liquid was being agitated. The mercury levels in the isotensiscope were adjusted to within 0.5 mm. of each other, and the levels in the manometer then read with a Societe Genevoise cathetometer. Since some of the preliminary measurements were made with a Gaertner cathetometer, the two instruments were checked against one another and found to agree within better than 0.5 mm. over the

whole scale. For the pressures greater than 1000 mm., a meter stick was used, and later checked against the cathetometer scale.

The barometric pressure was taken from an open manometer which was read with the same cathetometer as above. The diameters of the reservoir and tube of this manometer were the same as those of the main manometer, to cancel out any bore correction. Brass scale corrections were applied to all readings.

Temperatures were maintained constant to ± 0.02° C., the absolute value being obtained to 0.01° by comparing the thermometers used with a platinum resistance thermometer calibrated at the ice point.

Results

The corrected observed pressures are shown in the second Column of Table I, as averaged values for all readings. The average deviation from the mean of all these results is 0.3%, and the overall accuracy is estimated to be 0.5%.

Table I. The Vapor Pressures of Dimethylamine

T° C.	$P_{mm.}$obs.	$P_{obs.}$—$P_{calc.}$ (a)	(b)	(c)	(d)
0	561.3	..	—2	—2	—1.4
15	1057	..	11	—3	0
20	1282	21	23	—5	0
25	1542	..	40	—10	0
30	1840	32	66	—19	—1
35	2177	—	100	—37	0
40	2559	36	144	—60	—1

(a) $P_{calc.}$ Values from Berthoud's (3) smoothed data in the International Critical Tables.

(b) $P_{calc.}$ Values calculated by the extrapolated equation of Simon and Huter (4).

(c) $P_{calc.}$ Values calculated by the extrapolated equation of Aston, Eidinoff and Forster (1).

(d) $P_{calc.}$ Values calculated by Equation (1), this paper.

Our values are compared with those of Berthoud (3) in Column 3 of the table. It is seen that his values lie somewhat below ours; but considering that he claimed an accuracy of only 0.1 atmosphere, the agreement is remarkably good.

In Columns 4 and 5 are found comparisons of our data with values calculated from two empirical equations, extrapolated from temperature ranges lower than ours. Both equations were derived from the results of very careful measurements, and give the same value at 0° C., 563.5 mm., which is within the limit of error of our results. At the high temperatures where the equations are extrapolated considerably, Simon and Huter's equation (Column 4) gives low values, while Aston, Eidinoff and Forster's equation (Column 5) gives high values.

Since neither equation yields satisfactory results in our range of temperature, an empirical equation was derived for temperatures between 0 and 40° C. This equation is:

$$(1) \quad \text{Log}\, P_{mm} = \frac{-2354.3}{T} - 7.433\text{Log}_{10}\, T + 29.47675,$$

where T is the absolute temperature. The agreement between the observed values and those calculated by means of this equation is shown in Column 6 of the table. The differences are well within our limit of error.

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GEOLOGY and GEOGRAPHY

Chairman: A. H. MEYER, Valparaiso University

Professor E. R. Smith, DePauw University, was elected chairman of the section for 1945.

A new explanation of the circulation of the atmosphere, A. V. LOTT, Sellersburg.—This explanation of the circulation is based upon the view that the major atmospheric movements are due primarily to the heating and the expansion of the air which lies immediately above the earth's surface. This heating and expansion raises the cold air of the stratosphere to such a high level that it affects the earth's surface in middle latitudes only during the winter months. However, a cooler sun produces less heat and the ensuing expansion is unable to force the stratosphere up to its former high level. Therefore the base of the stratosphere descends. This movement, which permits the cold air of the stratosphere to be brought down to the earth's surface by the circulation around the basic centers of action and the migratory air masses, ushers in a cold period of earth history which must continue as long as the base of the stratosphere remains at the low level. The temperature of an air mass varies inversely with its altitude. Therefore, temperatures at the base of the stratosphere rise as the stratosphere descends. This eventually causes the earth to become covered by a stratosphere which is warm at its base, and then the former cold period develops into a warm period which must continue as long as the base of the stratosphere remains at the critically low level. When more heat is received from the sun there is greater expansion in the troposphere. This raises the base of the stratosphere to a higher level. Its temperature falls and the colder air is brought down to earth in the higher latitudes. Thus the warm period gradually develops into a cold period which continues until the base of the stratosphere either rises or descends, a descending stratosphere bringing on another warm period while a rising stratosphere introduces a climate like that of today.

Effective organization and functioning of geography a challenging issue in American education. ALFRED H. MEYER, Valparaiso University. —War agencies, journalists, and professional educators in the United States have been shocked at our civic unpreparedness to think of present day national and international problems in geographic terms. Questionnaires submitted by the writer to both college and high school authorities concerning the status of geography organization and instruction reveal an unwarranted divergence of opinion as to the true nature, functions, and objectives of systematic and regional geography.

If geography is to share responsibility with the other sciences, social and natural, in a citizenship training program which embodies an understanding of global realities, then geography must not only be given a

recognized place in the educational curricula of our country, but it must be taught and functionally integrated with other disciplines on a sound philosophical and academic basis. To this end it behooves us to examine some of the chief historical contributions to the field, particularly those which reflect the philosophical and functional aspects of geography as a unique chorographic science.

Status of geography and geology as subject matter in the curriculums of colleges and universities of Indiana. BENJAMIN MOULTON, Indiana University.—In response to the growing interest in geography the question arises as to the availability of such training in the colleges and universities of Indiana. Data on the training offered was obtained from the catalogues of the institutions involved. Conclusions are: Eighteen schools of twenty-one offer three semester hours or more of geography. Geography courses in almost one-half the institutions are taught by teachers who are not specialists in geography. Of Indiana's six institutions of over 1,000 students two do not offer any appropriate training in geography, one offers only 12 hours. Only five institutions offer training that would adequately prepare for the teaching of high-school geography.

The future need of geography as a cultural course and in the training of teachers is sufficiently important that there is need for improvement in geographic instruction in Indiana's colleges and universities.

Notes on the Pleistocene of Palm Beach County, Florida. ERNEST RICE SMITH, DePauw University.—Through a zone some six to eight miles west of the present Atlantic coast, a few feet below the surface, are found highly fossiliferous Pleistocene marls. They are some three to six feet in thickness and their remains may be found along many of the drainage ditches crossing the zone. Fresher material, however, can be obtained from the marl pits operated by the Palm Beach County Highway Commission, especially at the Hypoluxo and Cross State Pits. Earlier studies of these deposits have been based on the spoil banks along the drainage ditches and various investigators have determined their age to be of the Pamlico terrace of the last interglacial period. Practically all species are identical with those found on the east coast of Florida today, although there is considerable difference in percentage of given species in the faunas between the Pleistocene and the Recent. There are abundant representatives of Protozoa (Foraminifera, both arenaceous and calcareous), Annelida, Mollusca (all except the Cephalopoda) and Arthropoda (chiefly Ostracoda, Cirripedia and Malacostraca) together with sparser Coelenterata (Anthozoa), Bryozoa and Chordata (Otoliths of Pisces).

Variations in the Growing Season—Vigo County, Indiana

G. DAVID KOCH, Indiana State Teachers College

In Vigo County, Indiana, as is true in all counties of the state, the length of the growing season is one of the most significant climatic factors in limiting crop production. The wide variation from year to year in the dates of the last killing frost in spring and the first killing frost in autumn creates a hazard only too well recognized by the average farmer. In view of that fact a knowledge of the probabilities relative to the variations in the frost-free season[1] are highly desirable. The

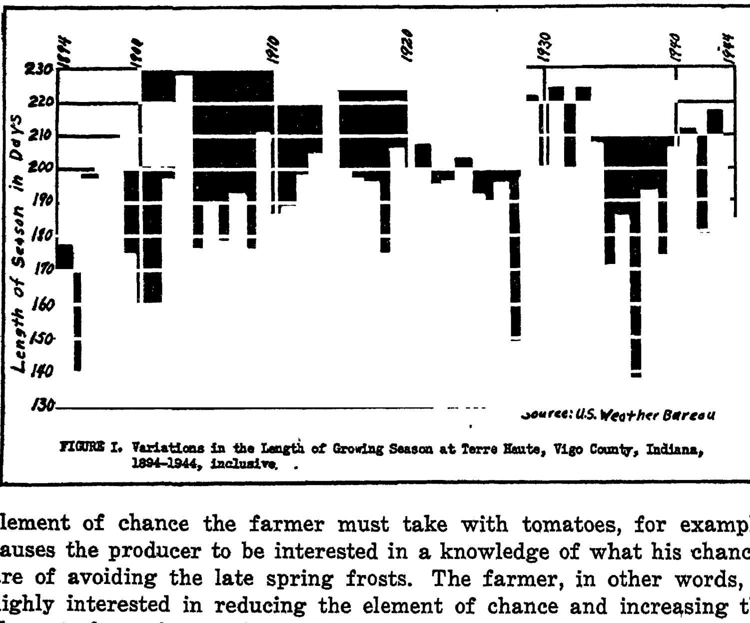

FIGURE I. Variations in the Length of Growing Season at Terre Haute, Vigo County, Indiana, 1894–1944, inclusive.

element of chance the farmer must take with tomatoes, for example, causes the producer to be interested in a knowledge of what his chances are of avoiding the late spring frosts. The farmer, in other words, is highly interested in reducing the element of chance and increasing the element of certainty with respect to planting and harvesting dates.

Many commendable studies have been made, and the results published, of weather phenomena in Vigo County and Indiana as a whole. Among the studies those dealing with the growing season have been noteworthy. However, such studies have usually been based upon the average growing season and variations therefrom. In working out the data for Vigo County, the median rather than the average dates have been used. The 20, 40, 50, 60 and 80 percentiles were used as a basis of analysis. By use of the median it is believed that a more comprehensive

[1] The term frost-free season is used in this study in the same sense as the growing season.

and meaningful analysis of the possibilities of late spring and early autumn frosts may be secured. Hence the results of this study are presented upon the above mentioned merits.

The only United States weather bureau station in Vigo County is located in Terre Haute, where continuous records of frost data have been recorded for a period of 51 years.[2] During this period the median length

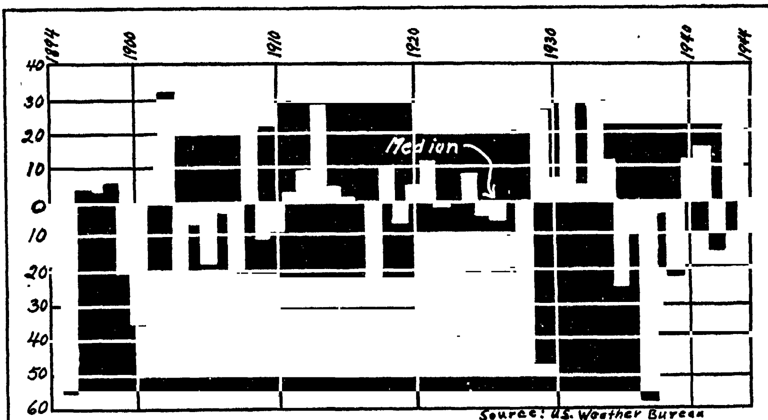

FIGURE II. Variations Above and Below the Median Length Growing Season - Terre Haute, Vigo County, Indiana, 1894-1944, inclusive.

of the frost-free season was 195 days. This means that in the past 51 years 50 per cent of the time the growing season was 195 or more days in length. Calculations for the other four percentiles were as follows: 20 per cent, 204 or more days; 40 per cent, 198 or more days; 60 per cent, 190 or more days, and 80 per cent of the time the growing season was at least 176 days in length (Table I).

Table I. Length of the Frost-Free Season—Terre Haute, Vigo County, Indiana—1894-1944, Inclusive

Per Cent of Time	80%	60%	50%	40%	20%
Length of season in days	176 or more	190 or more	195 or more (Median)	198 or more	204 or more

The variations in length of the frost-free season are great (Figure I). The longest season on record was 228, while the shortest was 138 or a variation of 90 days. This difference is sufficient for the maturity of several crops produced by Vigo County farmers.

[2] All of the data used as a basis for this study are those published by the United States Weather Bureau.

The yearly variations show little or no symmetry nor regular fluctuations. For example, in 1928 the season was 149 days in length as compared to 222 days in the following year. However, during the six-year period from 1929 to 1934, inclusive, the frost-free season was at no time less than 200 days or five days above the median (Figure II). During the next five-year period, 1935 to 1939, the season was never longer than 193 days or 2 days below the median for the 51-year record. These data indicate clearly the constant hazard presented to the farmer.

Not only does the variation in the actual length of the growing season present a hazard to crops but variations in the dates of the last killing frost in spring and the first killer of autumn also present problems. During the 51-year period under discussion the last killer in spring has occurred as early as March 17 and as late as May 29 at Terre Haute. This is a difference of 73 days. The median date for the last killing frost in spring was April 13 (Table II). Twenty per cent of the time

Table II. Per Cent of Time Last Killing Frost of Spring Occurred on Certain Dates at Terre Haute, Vigo County, Indiana, 1894-1944, Inclusive

Per Cent of Time	80%	60%	50%	40%	20%
Date	April 2 or later	April 9 or later	April 13 or later (Median)	April 14 or later	April 21 or later

the date was April 21 or later; 40 per cent, April 14 or later; 60 per cent, April 9 or later, and 80 per cent of the time on April 2 or later. As was true with respect to the lack of uniformity in yearly fluctuations so it has been with successive yearly dates of the last killing spring frosts. For example, in 1938 the last killer occurred on April 9, four days ahead of the median date while during the previous spring of 1937 the date was May 29, the latest date on record. In 1928 and 1929 the dates were April 28 and March 17, respectively. Numerous similar examples are present in the data.

Table III. Per Cent of Time First Killing Frost of Autumn Occurred on Certain Dates at Terre Haute, Vigo County, Indiana, 1894-1944, Inclusive

Per Cent of Time	80%	60%	50%	40%	20%
Date	Nov. 2 or earlier	Oct. 27 or earlier	Oct. 23 or earlier (Median)	Oct. 20 or earlier	Oct 12 or earlier

Source of data: U. S. Weather Bureau.

The median date for the last killing frost in autumn was October 23 for the 51-year period under consideration. The earliest date for the fall was September 24, and the latest date was November 23, or a fluctuation of 60 days. This is 14 days less than the variation between the dates for the spring frosts. Twenty per cent of the time the first killing frost of autumn did not occur until November 2 or later; 40 per cent of the time on October 27 or later; 60 per cent of the time on October 20 or later, and 80 per cent of the time not until October 12 or later.

Only three times since 1894 has the first killing frost occurred before October 1. These dates were in widely separated years, 1899, 1928 and 1942.

One may rightfully inquire just what value the foregoing data may have for the agriculturist of Vigo County. The farmer who has data of this type available is better able to judge when and what per cent of the time to expect frosts in spring and fall. For example, a farmer who wishes to grow an early crop of sweet corn will take a 20 per cent chance of it being killed by a late spring frost after April 21. On the other hand, unless the farmer's corn or soy bean crop is matured by October 20, there is a 40 per cent chance of these crops being caught by a killing frost.

It becomes apparent that numerous other possibilities may be computed. By using quartiles of fives, close predictions may be made. In the use of any of these data it must be assumed that the records of the past are a safe criterion in making forecasts for the future. Only thus are the data of value for prediction. However, since the record is comparatively short and the variations are large it is not claimed that the figures presented may be used as a final basis for forecast. They do, however, present the conditions that have obtained during the past 51 years at Terre Haute in Vigo County, Indiana.

High School Geography and College Grades in the Subject

S. M. McClure, Indiana Central College

The inclusion of geography in the Army training program, while presenting numerous administrative and teaching problems, afforded at the same time an unusual opportunity for observation on various phases of the teaching of the subject, including, among others, the content of the course, the sequence of major topics, teaching methods and techniques, testing procedures, and the influence of various factors on student achievement in the subject.

This paper is an attempt to evaluate one of the last-named factors, namely, the influence of high school training in geography on college achievement in the subject. The final course marks are taken as the measure of achievement. The marks of students having previous geography training are compared with those made by students lacking such high school credit.

An Army unit of air corps students stationed at Indiana Central College, Indianapolis, furnished the bulk of the data; a chance observation had indicated that an unexpectedly high percentage of these men had previously studied high school geography. Marks in recent civilian classes in the subject at Central, plus those of two sections at McKendree College, previously taught by the writer, give a smaller number of records. It is possible that the marks of these civilian classes present a more nearly normal picture of the average college situation than do those of the Army trainees. In all, the records of approximately five hundred individuals were studied.

Both the Army and the civilian classes were given essentially indentical courses as to subject matter, text, sequence of topics, and methods of instruction. The syllabus of the civilian course was modified but little to meet the outline (1) of the Army training program.

In general, the sequence and content of the work followed that of Finch and Trewartha (2). This text was used in both civilian and service classes. Methods of instruction varied with each class from an informal lecture to a recitation or quiz. No laboratory work was given but an effort was made to compensate in some measure for its absence by a brief study of rock and mineral specimens, reading of weather instruments, out-of-class assignment of topographic and weather map study, the use of films, slides and similar devices. The instruction was given by Dr. W. E. Stoneburner, Mr. Roy V. Davis and the writer in about equal amounts.

Several minor differences, however, did exist between the courses given the two groups of students. The class work of the Army men was concentrated into twelve weeks of daily classes while the civilian students met three times a week for one semester. The effects of this difference in spacing of classes is not known but may be of some importance as to the

amount of time available to the civilian students for study and reference reading.

Little reference work, other than that of atlas study, was expected of the Army students, while civilians were regularly given library reading assignments and this work was included in the reviews. Such additional reading opportunity may be somewhat significant since the lack of high school geography might be largely compensated for by individual library study and thereby reduce the difference in achievement between such a student and one with high school geography credit.

A third minor difference lies in the testing techniques. In general, the Army men were given short-form, "objective" tests; with the civilian students, both the short-form and the essay type of examinations were used. This difference appears to be of little importance.

While these three differences may account for minor variations in achievement between the civilian and the service student, it does not appear that any one or any combination of these factors is of significance for the purpose of this study.

Examination of the data of this problem show several sources of error which, while trivial, tend to lower the critical value of the inferences drawn. These factors are first, the total number of individual marks, approximately five hundred, is smaller than desirable for statistical accuracy. It is the maximum number, however, for which records are available in this particular course; it is probably sufficiently large to yield statistically significant data for this type of problem.

A second source of error lies in form of the Army student record; this did not always clearly differentiate between high school and college geography training. The number of such records involving geography are known to be few, however, and affect less than 3 per cent of Army marks.

Because of the transfer of Army students, several sections did not complete the entire work of the course; in these cases, the mark given is that of the quality of work done to the date of the withdrawal. These marks are, therefore, more significant for beginning portions of the course than for the later topics.

In the absence of any control technique, all other factors affecting achievement are left out of consideration. This factor is inherent in the problem as conducted, but it is believed that the number of individuals considered tends to off-set any selective effect and accumulation of error.

While these four items, and possibly others not considered, tend to lower the value of the data used, none of them are considered of sufficient importance to invalidate the findings that follow.

Data and Findings

A. Treatment.

In analyzing the data, an effort is made to avoid the terms and treatment of educational statistics and to present the materials in a less technical manner. Where letter marks were recorded, these have been given approximate but uniform equivalent percentages values. The term

"average" is used for the statistical term "mean." "Final grade" has previously been defined.

B. Data.

Of the 512 students whose final grades are considered in this paper, 204 had previously studied some phase of geography at the high school level; 308 had no such preliminary training. The first group is here designated as "plus students" and the latter as "minus students."

The entire number of students represent 17 classes of which 12 were service men; these dozen classes include approximately two-thirds of the total and it is in these classes that the most of the plus students are found.

The plus and minus students were not segregated in any of the classes; in fact, efforts to obtain this information were not begun until 1943 and the instructors did not know to which group a student belonged.

The average final grade of the 204 plus students is 80.6%; that of the 308 minus students is 72.9%. The difference in favor of the plus group is 7.7 percentage points; on the percentage basis, a difference of this magnitude is considered significant.

In 13 of the 17 classes, the plus students ranged in grades from 3.7 to 18.5 percentage points higher than the minus students. In three classes, the minus student average was from 0.5 to 2.4 percentage points higher than the plus group. One class included no plus students but the average of this group was below that of the other three just mentioned. This consistent showing in 13 of 16 classes indicates the persistency of the cause of the difference in achievement.

Of the 49 unsatisfactory grades recorded, 14 were made by the plus students and 35 by those from the minus group.

These three items—differences in average grades in the entire group, the showing of each group by classes, and the disproportionate distribution of failures between the two groups—are taken as the most significant items of the data. The mode and the mid-score show similar central tendencies; quintile groupings by grades give a preponderance of plus students in the upper fifths with the lower divisions containing an undue number of minus students.

Conclusions and Discussion

Within the limits of this study, it is concluded that

A. Students having high school training in geography, consistently obtain significantly higher grades in the college course than do students lacking this training at the high school level;

B. A significantly larger number of the latter do poor or failing work than do those of the first group;

C. This difference in quality of work persists throughout the course but appears, on the basis of incomplete evidence, to be more pronounced in the beginning portions;

D. Further investigation is needed to establish the basic facts and factors in the situation.

If other studies confirm in any major degree the conclusions reached above, several pertinent questions are at once suggested. Is the difference in achievement due to a carry-over of information from the high school course or is it due to some other factor? If the freshman course does duplicate in part the high school work, just what portions are repeated? Is it desirable or possible to avoid this duplication, particularly if "minus students" are in the class? Should the freshman geography enrollment be sectioned on the basis of high school credit as is frequently—and profitably—done in chemistry? If the plus students are segregated, how should the course for them be revised or arranged to articulate with the high school course? Should such a revised course treat geography as a factual or an interpretative study?

The answers given to these and similar questions by college teachers of geography may assume more than minor importance in guiding the anticipated development in earth science instruction (3) both at the high school and college level.

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Indiana Floods

STEPHEN S. VISHER, Indiana University

Floods are frequent in Indiana, local ones occurring somewhere nearly every season, and widespread ones occurring every few years. The following discussion is a companion to the study of "Drouths in Indiana" in *The Proceedings* for two years ago. The frequency of floods reflects four main conditions: (1) The abundant rainfall yields much water which must either soak in, evaporate, or run off. During the cooler months there is little evaporation, and the soil is often soaked, with the result so that there is much runoff. (2) Much of Indiana's rainfall occurs in considerable concentration. (3) In much of Indiana the runoff channels are inadequate in size and number to carry off the water of hard rains. This is partly a temporary condition resulting from the geologically recent glaciation. In the central and northern glaciated two-thirds of the State, natural drainage is incomplete or inadequate; much of that area is poorly drained because the stream courses have not yet been well developed or eroded to sufficient size. Each century the drainage of that region is becoming a little more adequate to carry off the excess rainfall, but insufficient time has elapsed since the glacier melted away to permit valleys to extend to all parts of the area and to provide adequate drainage channels. That region still is in the stage known as "physiographic youth" or (in parts of northern Indiana which are almost entirely undrained) "physiographic infancy". In the unglaciated section and that covered by the older Illinoian ice sheet (approximately the southern third of the State) although natural drainage courses are numerous and the relief is in most places "physiographically mature", nevertheless floods are rather frequent because of three special conditions. One of these is that rain frequently comes with notable intensity. Another condition favoring floods is the fact that the lower courses of several of the streams, notably the Wabash and the White, were partly filled by alluvial deposits as a result of special conditions prevailing during the Glacial Period, when these rivers were excessively loaded with glacial materials. Their wide, fertile alluvial plains are inviting to farmers, but partly because of the meandering, clogged streams, they are relatively often flooded.

The third main reason why there are many floods in Indiana and the fourth why southern Indiana, despite its numerous valleys, has many floods, are that changes produced by man have taxed the streams beyond their natural capacity. Deforestation has greatly increased runoff as have extensive drainage operations by open ditches and by tiles. Indiana has many miles of drainage ditches, 20,787 miles according to the 1930 Census of Drainage. Moreover, detailed estimates of tile drainage indicate that there are in the State a total of many thousand miles of small tile in addition to the 10,439 miles of large tile such as storm sewers,

reported by the Census. These tile rapidly bring to the open ditches vast amounts of runoff water which otherwise would have stayed longer on or in the ground. This increased percentage and rapidity of runoff and the flooding caused thereby, and also the extensive erosion of cultivated hillsides have carried large amounts of soil and other materials from the higher levels into the stream channels, partly clogging them, thus reducing their capacity for rapid transportation of water. Consequently in times of high water, the rivers must spread beyond their normal channels.

Another human interference with runoff, which is of at least local importance, is the restriction to natural stream flow imposed by numerous graded roads and railroads crossing valleys, and by bridges constructed with a view toward saving money even though such bridges do impede the flow of streams. It does seem foolish, to those who have little considered the hazard, to build a large, long, and high bridge over a comparatively small stream, and to refrain from damming the valley by a high road grade. But repeatedly in Indiana, short, relatively inexpensive bridges and road grades in valleys have been seriously damaged by floods, with the result that replacement or extensive repair has required a total financial outlay greater than would have been required for an adequate bridge and a properly opened, graded road across the bottom land. The inconvenience and loss caused to citizens by the closure of roads for such replacement or repair of inadequate bridges and grades is a cost which is hard to estimate, but which is quite considerable in a region where population is as numerous and travel as extensive as in modern Indiana.

Floods vary greatly in magnitude, and the damage they cause varies with magnitude and with season of occurrence, and especially with the extent of human adjustments to them. Where flooded areas contain few people and little constructed property, floods may do little damage. In this article an effort is made to summarize the occurrence of floods of four magnitudes—local, moderate, widespread, and great—and also to point out methods of reducing the damage that future floods of similar intensities will cause. Under the latter head, flood predicting is mentioned. Details on occurrence are given following a brief discussion of types, causes, and ways of reducing the damage.

Local floods are caused by excessive local rainfall. A rain of two or three inches may cause a local flood upon relatively flat land, such as a city site, if it falls within an hour or two, as sometimes happens. The frequency of rainfalls of such an amount in Indiana is discussed elsewhere, where data on the maximum rainfalls which have occurred in various short periods from five minutes to six days are also mapped and discussed. A local rainfall of several inches within a day or two is sure to cause some local flooding not only of poorly drained areas, but also of those with small valleys.

Floods of a small river basin, for example the East Fork of the White River, are caused by several days of heavy rainfall over a large part or all of its basin. The larger the area drained, the more widespread or excessive the rains must be in order to cause a flood of the main stream.

This is because stream valleys are prepared to carry away the normal amounts of runoff and hence large basins normally have developed large drainage channels. Indeed, as the valleys were carved out by the runoff water itself, especially that of times when more than the normal amount occurred, floods seldom occur unless there is considerably more than the normal amount of runoff. The chief exception to this rule occurs when special conditions interfere with runoff. Examples are the partial blocking of valleys by ice, road grades, or levees, and by an unnatural increase in runoff such as that caused by drainage projects. (The sudden release by warm rain of previous precipitation accumulated as snow, although an important cause of floods in some regions, is of minor import in Indiana.)

Widespread floods (the third magnitude) which occur once every few years are the result of excessive rainfall over a large area. Such floods are much more important than are the more restricted floods just mentioned, chiefly because they affect larger areas, even though they may not cause any more damage in any particular small area than are caused by local floods.

The final category here considered are the "great floods", the worst in a generation or a century. These are due to excessive rainfall over a large area, and their height is little affected by anything man has done. Floods as great as any which have occurred in recent years certainly have occurred in most regions before there was any appreciable amount of deforestation or artificial drainage, or before man-made obstructions to the valleys were constructed. In other words, although the frequency and severity of local and ordinary floods clearly are affected in several ways by human action, the "great" floods are meteorological phenomena that are almost completely uninfluenced by man. They come whenever sufficiently excessive rain falls, they require such large amounts of precipitation that the soil even of forested land, the reservoirs, and other catchment basins are filled to overflowing, and the levees are inadequate to hold the streams in place. For example, the record-breaking flood of the Ohio River in January, 1937, resulted from a rainfall of eight inches or more falling during a three-weeks' period over much of the Ohio Basin (from Ohio, Tennessee, and Kentucky to southern Indiana) following heavy rains in late December and early January. The January rainfall averaged 15.4 inches in Kentucky, 14.7 in Tennessee, 9.8 in Indiana, and 9.4 in Ohio. For each of these states, those totals set new January records. For the 30 days December 27, 1936—January 25, 1937, 33 Indiana Weather Bureau stations each received more than 15 inches of precipitation. Five of them received from 20 to 22.38 inches.

Experts have calculated that the several dams on the Upper Ohio River and its tributaries did not reduce the height of the great 1937 flood of the lower Ohio River more than one or two per cent, an almost negligible amount. This was because vast amounts of rain fell after the reservoirs were filled.

Thus, it appears that not only are these great floods not in any way the fault of man but that he can do almost nothing appreciably to reduce their frequency or height. Levees merely somewhat increase the

height of the flood, at least until the levee is broken. It is, however, clearly possible to reduce the damage which floods cause.

Methods of Reducing Flood Damage

Four chief ways of reducing flood damage are: (1) Reduce the number and severity of floods by retarding runoff in the upper stretches by increasing absorption by the soil (as by reforestation, strip farming, and contour plowing), and by creation of storage reservoirs. As already remarked, this method is entirely ineffectual after sufficient rainfall has fallen to saturate the soil and to fill the reservoirs. (2) "Improve" the stream channels by removing obstructions to stream flow to reduce locally the flood height. This procedure, however, increases the height of the flood farther down the valley. Its effect is opposite to the first procedure, that of retarding runoff. (3) Build barriers (levees) against the flood to confine the high water to areas bordering the normal course of the river. Levees increase the height of the flood (except in the protected area), by confining the water to a narrower channel. Moreover if the flood overflows or breaks the levee, the resulting damage may well be distinctly greater than would have occurred if there had been no levee. This is partly because levees give a false sense of security and thus encourage improper land use. Deposition along the stream bed between the retaining levees commonly causes the stream to flow at an ever higher level, with the result that progressively higher levees are required to confine the stream. Furthermore, insofar as levees are effective in preventing any flooding of the bottom lands, they also prevent the deposition of silt there, and consequently inhibit the upbuilding and natural fertilization of the bottom lands. In other words, a system of levees which prevents any flooding of the adjacent flood plain results in serious injury to the flood plain by causing the confined river to flow at an increasingly higher elevation above the flood plain. This seriously interferes with the natural drainage of the bottom land, and at the same time the lack of flooding means the absence of natural fertilization; flood plains are valuable primarily because they are relatively fertile.[1] (4) The fourth and most effective way of reducing flood damage is by making adequate allowance for and adjustment to floods. Flood prediction is one aspect. Studies of the flooding effects of various amounts of rainfall and other conditions are essential. The predicting of the height and time of the crest of a flood is done both on the basis of observations further upstream and by deductions from meteorological and surface conditions. Structures necessarily placed near streams, such as bridges, and some roads, should be constructed in such a way as to withstand floods, and at the same time not to be a significant contributing factor. To do this efficiently requires knowledge of the flood conditions which are to be expected. It is of special importance that the areas subject to flood have their use restricted in such a way that a minimum amount of damage will be done by the flood. Permanent residences, for example, should be prohibited, at least those which are not cheaply replaceable; only such livestock and so forth as can be readily removed should be allowed. In general, areas

which are frequently flooded should be devoted to forest growth for which they are especially well adapted and useful, now that timber has become valuable. If farmed, such low land should be planted in some crop which is relatively little subject to flood damage. Farmers who plant these areas should reside on considerably higher land and should be able to accept the financial risk of losing an occasional crop in order to harvest higher yields from rich land most of the time.

A thorough classification of all the land of Indiana as to its suitability for various uses should be made. Land should be used in the ways believed by competent authorities to be the most advantageous from the viewpoint of the general good over a long period. It has been suggested that such wise use might advantageously be encouraged by flexible taxation. For example, wisely used rural land could be taxed lightly; land which was used with moderate suitability could be taxed moderately; land which is used in a way clearly contrary to the better interests of the community and nation could be taxed heavily. Land subject to frequent flooding certainly should not be used in the ways in which much of it is now used. Merely because it is poor for residential purposes, and hence cheap, is no justification for having much of the low land of Indiana's cities occupied by numerous poor dwellings. Likewise, merely because it is convenient to live near to one's fields is no justification for having permanent and costly farmsteads in places that are subject to flood, with consequent loss of property and perhaps lives. Despite the strong American rebellion against restrictions of freedom of action, such restrictions are becoming increasingly necessary.

The modern availability of communication and transportation, while improving some possibilities of adjustment to floods, for example, prompt removal of livestock, has made for a wider knowledge of human suffering in flooded areas which leads to mental suffering by sympathetic people elsewhere. Moreover, the people of neighboring areas are adversely affected financially by sharing the losses caused by the floods. They do so in many ways, partly through voluntary contributions for relief, partly through being compelled to pay higher taxes to raise money appropriated for relief and rehabilitation, and partly because of the higher prices they must pay for certain services and goods as a result of the flood. Hence there is real justification and social desirability for enacting and enforcing regulations to prevent permanent residence in areas subject to serious flooding and to restrict the use of those areas in such a way as to cause

[1] Because of these well-recognized drawbacks to levees, the world's most expensive levee system, that along the lower Mississippi River, is being seriously questioned, even partially abandoned. This is despite the urgent political pressure imposed by people taking a short view of the matter, who insist that levees are essential. One phase of the partial abandonment of the Mississippi levee system takes the form of deliberate breaks in the levee with the result that large prescribed areas are flooded, thus temporarily checking the rise in the river level, and reducing the prospect that an undesired break will occur elsewhere in the levee. In the areas thus deliberately flooded, the flood damage is relatively slight because the use of those areas is restricted in such a way as to render flood damage small.

a minimum of anguish and loss not only to the local people but to numerous others.

Floods of the White River

Five especially high floods of the White River were those of 1828, 1847, August 1875, March 1913, and January 1930. The floods of February, 1916, January, 1937, and April, 1939, also were high. The floods of 1930, 1913, and 1875 reached approximately the same heights as did those of 1828 and 1847, both of which apparently were somewhat higher than the more recent ones. The earlier floods caused much less damage, however, as relatively few people resided in the valley in 1828 or 1847. The flood of 1875 did more damage than that of 1913, except in Indianapolis, because it occurred in late July and early August, and destroyed most corn, while the 1913 flood occurred in March before corn was planted. The increase in bridges and road grades in the valley, which had occurred between 1913 and 1930, resulted in greater damage by the later flood. Moreover, a considerable share of the corn crop of 1929 on the bottom land had not been harvested prior to the January, 1930, flood, because much of the land had been almost continuously too wet to permit the use of wagons. Hence the 1930 flood caused greater destruction along much of the valley than did the 1913 flood. The chief exception was in Indianapolis, where the 1913 flood did much the greater damage, several millions of dollars worth in the western and southwestern parts of the urban district. The 1913 flood is estimated to have taken the lives of 200 people in Indiana (on other rivers as well as the White) and to have driven 200,000 people from their homes. The estimated number of persons driven from their homes in Indianapolis was 35,000; at Rushville, the entire business district was inundated.

Floods on the Wabash River

The lower Wabash River carries the drainage from two-thirds of Indiana as well as from a small part of Illinois. The upper Wabash, above the mouth of the White River, is a much smaller stream, draining less than a third of the State, only a little more than is drained by the White River (11,481 versus 11,155 square miles). Moreover, the upper Wabash Basin has less runoff than the White, both because it receives less rainfall, especially during the cooler months, and because much of it is relatively level, in contrast with the "well-drained" character of much of the White River Basin. In this discussion it is therefore desirable to distinguish between the upper and lower Wabash, the latter including that below the mouth of the White River.

High floods on the upper Wabash (based on data for Terre Haute for 1905-1939) occurred in January, 1907, March, 1913, August, 1915, February, 1916, November, 1921, April, 1922, September-October, 1926, June and December, 1927, January, 1930, May, 1933, July, 1938, and March, 1939. The highest of these floods was that of 1913 when on March 27, the crest was 17.3 above flood stage. The next highest floods were on May 16, 1933, and March 16, 1939, when the crests were 11 feet

above flood stage. In 1907, (January 23) the crest was 10.7 feet above flood; in 1922 (April 19) it was 10.4 feet; in 1916 (February 2) it was nine feet; it was about seven feet above flood stage on December 5, 1927, October 7, 1926, and July 4, 1938. The highest water (1905-1939) during June was only four feet above flood stage (June 1, 1927) while August had no flood in these years, the highest water level being two feet below flood stage. At Vincennes, the crest of the January, 1930, flood was higher than that of March, 1913, flood, but this greater height in 1930 is believed to have been due to the presence of levees which held, whereas the levees of 1913 failed to hold. Floods which did especial damage in the Wabash Valley were those of 1913, 1930, and 1937. In 1913, for example, two-thirds of the city of Logansport was submerged, some of it to a depth of 15 feet. At Lafayette, the river reached 22 feet above flood stage and was three miles wide. At Peru, Kokomo, and numerous lesser places along the river, many citizens were compelled to flee.

Floods on the Ohio River

The Ohio River is scarcely in Indiana, because when Kentucky was established, its northern boundary was the north bank of the river. The U. S. Supreme Court has, however, ruled that the boundary between Indiana and Kentucky is along what was the north bank in 1816, when Indiana was admitted to statehood, instead of along the present north bank. Since the river shifts continually, small parts of the river now are within Indiana. During floods, of course, considerable stretches of Indiana's bottom lands are covered.

The Ohio can carry such a vast volume of water that a serious flood scarcely could be caused by its Indiana tributaries. Moreover as floods on the Ohio affect other states more conspicuously than they do Indiana, discussions of Ohio floods have been made almost solely by non-Hoosiers. Cincinnati, the largest city on the Ohio proper, has been much affected by that river, and therefrom have come many valuable data as to floods.

The Ohio has, on the average, several floods a decade (62 floods in 67 years, 75 in 100 years) but few of them attain heights much in excess of flood stage, as when that stage is reached, the river is much wider and straighter than normal, and flows much more rapidly, and hence carries off much more water. Flood stage does not commence until the water attains a level about 50 feet above low water level at Cincinnati and Louisville, and about 35 feet at Evansville.

The 1937 flood was the highest on record, reaching a level of approximately 80 feet above low water level at Cincinnati, 87.4 feet at Louisville and 87 feet at Dam 43 (located 25 miles below Louisville) and 54 feet at Evansville. Never before in the United States, Devereaux declares, has a river flood attained a level as much as 80 feet above low water stage. The second highest flood of record of the Ohio River was in 1773, estimated to have attained a height of 76 feet at Cincinnati.

Four-fifths of the floods of the Ohio River are caused, Devereaux estimates, by heavy precipitation over the upper parts of the Ohio and

its tributaries, while one-fifth are caused by excessive precipitation in the region near Cincinnati and along the local tributaries.

The Ohio River floods have caused heavy damage to several Indiana river cities and towns. The 1937 flood, which at the crest, January 26 at Cincinnati, January 27 at Louisville, and January 31-February 1 at Evansville, reached heights of 28, 30 and 19 feet above flood stage, respectively, caused millions of dollars of damage in Indiana (especially at Evansville, more than two-thirds of which was under water, while 90,000 people fled from their homes). Jeffersonville was 90 per cent flooded and 13,000 people fled from their homes. Several lesser places were badly damaged, one of which, Leavenworth, has been largely abandoned in favor of a new town site on the upland.

The Ohio floods occur predominantly during the first three months of the year. Of the 18 greatest floods of 1832-1939, January had five, February seven, March, four, the other nine months only two. Of the 28 chief floods at Evansville, 1883-1939, only two had their crests after April 5, (April 23, May 20) and only two before New Year's Day (December 15, 30). March and January each had eight, February seven, April four, December two.

Thus a flood which attains a height of at least seven feet above flood stage at Evansville occurs in nearly half of the years, and in about one-eighth of each of the Januaries, Februaries and Marches.

Toponomy in Sequent Occupance Geography, Calumet Region, Indiana-Illinois

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Significance of Toponomic Studies

The term toponomy is derived from the Greek "topos," meaning place, and "onoma," meaning name. Thus toponomy has come to signify the science of place names as to origin, meaning, classification, and use.

The archeologist, the anthropologist, the historian, the geographer, and the philologist have long recognized the intrinsic value of the study of place names in their respective fields. Particularly is this true in Europe, where an extensive literature has been published on the subject. Interest in toponomy has more recently spread to America, and a number of American geographers have come to recognize the study of the origin and meaning of place names as a helpful device in regional geographic investigations and interpretations.

Objective and Technique

There occurred to us the idea that a toponomic study might take on increasing geographic significance if we attempt a partial chronologic-chorographic treatment of place names in addition to merely identifying place nomenclature, thus contributing to our knowledge of the progress of regional settlement and economic development.

Geographers are increasingly recognizing the fact that the mapping and analysis of only the present day occupance forms of an area are far from adequate in interpreting the manner in which the present landscape came to be occupied. Antecedent geographic environments must be pictorially reconstructed. This is often a difficult process. And so it would seem helpful to consider sequent occupance geographic toponomy as another tool to supplement other methodologies or techniques the geographer uses in making a complete areal analysis.

The inclusion of such place name study in the historical geography of an area is for the purpose of presenting as complete a picture as possible of what the occupants of any given period were thinking about concerning the region. What people think of their environment may be as geographically significant as the fact of the environment itself. And

[1] This represents the first of a series of papers being prepared on the chorography of the Calumet region on the basis of research grants awarded the author by the Indiana and Michigan Academies of Science. These grants are hereby gratefully acknowledged.

The author is indebted to Miss Norma Baumeister, who ably assisted in the collection and recording of toponomic data. He is also grateful to all correspondents, including librarians, who have contributed to the clarification of part of the place nomenclature.

what the pattern of environmental thinking has been from period to period is a significant part of the geographic history of a region.

Our study is based on the Calumet region of northwest Indiana-northeast Illinois and is pursued with the following principle in mind:

The various classified types of nomenclature motives, as generally recognized by toponomists, are included, but reference in the context is made chiefly to place names of primary interest to the development of our subject matter strictly from the geographic points of view,—systematic and regional. As such, no attempt is made to supply a complete place name nomenclature of the Calumet area, nor does this paper purport to be a critical or professional philological treatise of such place names.

The Calumet toponomy is illustrated cartographically by a map of representative place names for each period of the sequent occupance referred to below. A more complete inventory of place names than is found in the text and maps appears in a geographic classification table (Fig. 5) at the end of this paper.

Included in this paper are several place names which either have not appeared at all on any published maps or have appeared only as "phantom" city plats, or represent places which no longer exist but which have contributed their part to the development of the region.

The Calumet Region

Geographic Position. Few regions in the United States can compare in importance with the strategically situated Calumet area at the head of Lake Michigan (see map). This lake, which both Indiana and Illinois were destined to share, dips down deeper into the heart of the Central Plains than does any other of the Great Lakes. Thus the Calumet, from the earliest days down to the present, has felt the effects of the "cul-de-sac" (Fr., lit. "bottom of a bag") geographic position on travel and traffic,—by the Indian, who founded the old Sac Trail connecting Detroit with Rock Island; by the French explorer, missionary, and fur trader, who discovered the portage connection between the Great Lakes and the Mississippi; by the colonial frontiersman, who sought by this route a new home in the West; and finally by the road and railroad builder, who swung his highways and trunk lines from the East around Lake Michigan to connect Chicago, the metropolis of the Central West.

Calumet Appellations. The name Calumet has been applied, at one time or another, to more than a dozen and a half landscape forms—two rivers, a channel, a marsh, a lake, a harbor, a geologic formation, a township, four towns (Roseland, Calumet City, Chesterton, and Calumet), a gun club, a country club, a beach, a grove, two city parks, and multiple streets and industries. A golf course selected "Pipe O' Peace" as a suitable variant.

Calumet was the name also given by pioneers to the region between Wolf Lake and Lake George and Lake Michigan. Later the greater region about the head of Lake Michigan came to be known as the Calumet

region.[2] The multiple use of the term indicates its widespread sentimental and euphoneous appeal. Its regional use well expresses a chorographic reality coinciding roughly with the Calumet drainage basin and the essential homogeneity of its historic-geographic cultural development.

Recognized Stages of Sequent Occupance. Our toponomic treatment of this nationally famous transit region recognizes roughly four stages of settlement: 1. the occupance by the Indian and the French up to about 1830; 2. the preemption of lands by the squatter-pioneer, 1830-1850; 3. the development of general agriculture, 1850-1900; 4. the strongly competing urban and rural land-use forms, from about 1900 to the present. As is characteristic of all occupance periodization, the dates assigned to the stages here recognized and the toponomy associated therewith represent zonal rather than sharp border line time divisions.

The Geographic Toponomy of the Pottawatomie-French Occupance

"Calumet." This is a French corruption of an Indian term referred to in early documents and maps by more than a score of different spellings for one or the other of the Grand Calumet and the Little Calumet Rivers.[3]

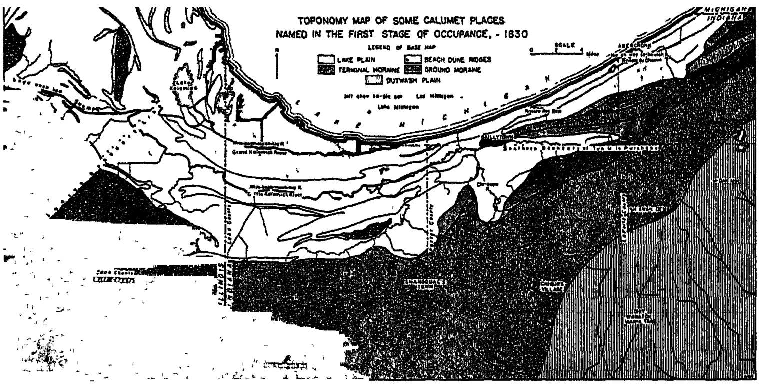

Fig. 1. The geographic toponomy of the Pottawatomie—French occupance. The head-of-Lake Michigan area at one time during this period was known as "Quadoche," also spelled "Quadoghe," as reported to the author by Marguerite H. Anderson, of the Indiana State Library.

Base map adapted, with the aid of government maps, after Fryxell's "The Physiography of the Chicago Region," 1927, and Cressey's "The Indiana Sand Dunes and Shore Lines of the Lake Michigan Basin," 1928 (courtesy of the University of Chicago Press).

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[2] "That the Calumet Region was once called by cartographers 'Quadoche' is revealed by the early maps of John Mitchell, 1755, and the Jeffery's map, 1761. The Huron Indians were called 'Quadoche' by the Iroquois. Since there was a tribe of Pottawatomi called the Huron Potawatomie, it is possible that this region was at one time the home of this tribe."—Works Progress Administration, Indiana. *The Calumet Region Historical Guide,* Garman Printing Co., 1939, p. 7.

[3] Calumick, Calumic, Colomique, Keliemanuk, Calamick, Kenomokonk, Kannomokonk, Calomick, Kenomick, Killomick, Kenoumick, Kenmonkyah (Pottawatomie), Gekelemuk (Delaware). The various dialectic spellings indicate the difficulty of translating Indian nomenclature. The spelling shown on the first Federal land survey maps of the area (1827) are "Calumic," and "Kalamick."

Sentimentally, Calumet means "the pipe of peace,"[4] referring to the numerous Indian peace councils reported to have been held on the banks of the Calumet rivers. But the original signification of the term seems to be definitely rooted one way or another in the physical environment. "It is explained that the French observing the Indian custom at ceremonial gatherings of passing a tobacco pipe from one to another as a token of amity, and noting also that the stem of this pipe (invariably decorated with brightly colored pendants, its most striking feature) was made of a reed from which the pith had been removed . . . dubbed the insignia with their word for reed, 'calumet'."[5]

Another supposition is "that the river was called Wimbosh-mash-kig, meaning Hollow Reed River, because of the heavy growth of reeds which fringed the stream. The French simply translated the word into the French, Chalumean, of which 'Calumet' is a dialectical form. . . ."[6]

These connotations, then, aptly call attention to the reedy vegetation of the Calumet marshes, which fact is substantiated by the first land survey of the area of more than a century ago.

But Calumet is also said to signify "a deep still water."[7] This also aptly characterizes the unique condition of a double-mouthed stream noted primarily for its sluggishness and stagnant waters which meander tortuously through an almost impassable marsh. The name "Calumet," then, is as geographically descriptive as it is euphoneous and sentimental.

"Saga-nash-kee." The modern Calumet Sag Channel, popularly known simply as the "Sag," derives from the Indian "Saga-nash-kee" (Rees map of 1851). In a manuscript by M. S. Barge, on file at the Chicago Historical Society, the Sag swamp is also referred to by name "Wabashikisibi,"— "Wabash from wab meaning white, ashk, grass; ike, ground, we have wabashiki, a bog or marsh, and wabashikisibi, 'a bog river'."

"Mit-chaw-sa-gie-gan." The history of the Calmet area is closely associated with Lake Michigan as pointed out above. In fact, the "bay" section of the lake is functionally an integral part of the Calumet.

This lake, the third largest in the United States and the sixth largest in the world, was appropriately characterized by the Indian "Mit-chaw-sa-gie-gan,"[8] interpreted "Great Water."[9]

Some early French cartographers preferred to name the great lake in commemoration of Indian tribes associated with it. Thus, on maps by Hennepin (1698) and Delisle (1703), we find Lac des Illinois and Lac des Poutouatomi.

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[4] Gemmill, William Nelson, *Romantic America*, Jordan Publishing Co., Chicago, 1926, p. 60.

[5] Works Progress Administration, *op cit.*, pp. 8-9.

[6] *Ibid.*, p. 9.

[7] Dunn, Jacob Piatt, *True Indian Stories*, Sentinel Printing Co., Indianapolis, 1909, p. 256.

[8] Other spellings: Match-i-h-gua-ing and Misch-i-gon-ong.

[9] Beckwith, H. W., "Indian Names of Water Courses in the State of Indiana," *12th Annual Report, Indiana Department of Geology and Natural History*, Indianapolis, 1882, map, opposite p. 42.

The Indian tribe occupying the Calumet area was known as the Pot-a-wat-o-mi,[10] a branch of the Miamis. The name signifies the "People of the place of fire," (Wau Feu-d'sbberille, 1650). The French Jesuits of the 17th century areally distinguished those Pottawatomies who dwelled in the forests from those who dwelled on the prairie, the latter being called the Mascowtens, which signifies "a treeless country,"[11] much of the early Calumet consisting of marsh prairies as again is revealed by the original Federal land survey.

Other Indian Nomenclature. Indian place names in the United States generally are not as numerous as a geographer would desire. There are several reasons for this. In the first place, Indians did not have the white man's concept of a region. Nor did his occupance take the form of organized permanent community settlements. His place names, therefore, are characteristically confined to natural forms of the landscape with which he lived in close adjustment. Of these, streams and lakes seem to hold first place as Indian landmarks of identification.

The Calumet region seems no exception to this. On a map of Indian names in Indiana by Daniel Hough[12] and another by E. Y. Guernsey,[13] there appear only the following Indian names for the Calumet region: villages: A ber cronk, mouth of Trail Creek, Michigan City (The Guernsey map puts the site of this village on the Lake Michigan shoreline farther to the southwest—at about Waverly; however the Michigan City site seems to be favored both authoritatively and environmentally.), Wan-a-tah (Chiy Wanatch), site of modern Wanatah, and Chiqua's Village, mile east of Valparaiso, M-dah-min (maize), vicinity Door Village; water forms: Me-oh-way-se-be-weh (Trail Creek), Chi-quew (Salt Creek), Mes-kwah-ock-bis (Cedar Lake).

Knotts refers to an important Indian town toponomically interesting on a site near what is now Westville—Ish-kwan-dem (the door). "This was a favorite location, being on the boundary of the prairie and at the entrance of the woods or forest. Hence the door, going into or coming out of . . . and from this place, the word LaPorte (the door) was more than likely derived."[14]

The Town of Bailly. A place name of this period, Baillytown, never to be forgotten represents hardly a "place" at all but simply a homestead founded in 1822 by Joseph Bailly, which took on the functions of a French-Indian trading post of unrivalled regional importance. Bailly's name and post are linked with those of the historically famous John Jacob Astor and the American Fur Company, the trading connections with which represent practically the only commercial activity of this period.

The intrepid French explorer, the resourceful trader, and the consecrated missionary soon discovered the need for charting and naming

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[10] There are numerous spellings.

[11] Smith, Huron H., *Ethnobotany of the Forest Potawatomie Indians,* Milwaukee Public Museum Bulletin, Vol. 7, No. 1, May, 1933, p. 16.

[12] *Ibid.,* pp. 42-43.

[13] Indiana Department of Conservation, Publication No. 122, 1933.

[14] Knotts, A. F., *Indian Trails, Mounds and Village Sites of LaPorte County, Indiana,* MS, 1932, p. 8.

the unnamed landmarks of the vast French domain in America, which prior to 1763, extended in a great arc from the Gulf of St. Lawrence southwesterly by way of the Great Lakes and the Mississippi to the Gulf of Mexico.

The Pre-eminence of Waterway Nomenclature. To the French voyageur and *coureur du bois*, as well as to the Indian, natural water bodies assumed first place of geographic importance. These were sought out for travel, for trapping, for trading, and for settlement. Consequently, many of the rivers and lakes first explored were destined to receive true French names or French-corrupted Indian names. Besides the term "Calumet," itself, at the head of Lake Michigan area, we note on early maps the Riviere du Chemin (the river by the trail) at the site of Michigan City.

To the student of sequent occupance, Indian trails are of the greatest significance in tracing the subsequent development of lines of communication, since, as we know, many of these aboriginal routes of travel explain the courses of present-day travel. Particularly is this true in the Calumet area. Trail Creek, as this stream is known today, marks a southeasterly course of travel which intersected the Pottawatomie trail along Lake Michigan connecting Chicago with Niles, Michigan.

Riviere des Bois (early French name of the small Sand Creek at Waverly) and its subsequent English equivalent "Stick River" suggest the large piles of driftwood accumulating at the mouth of this stream now practically obliterated.

The Geographic Toponomy of the Squatter-Pioneer Settlement

As we would expect, place nomenclature of the Indian-French occupance is related almost exclusively to features of the relatively unmodified natural environment—the Fundament. The removal of the Indian by a series of government treaties and the subsequent disposal of the public domain to the incoming settler marked the era of pioneer place-naming. All kinds of names reflective of the early settlers' social, economic, com-

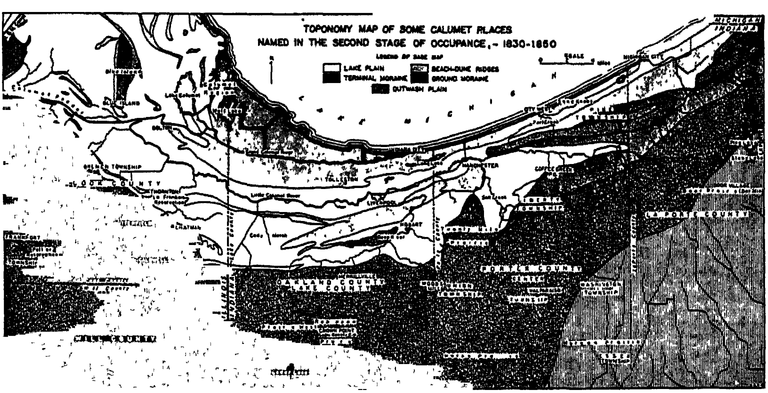

Fig. 2. The geographic toponomy of the squatter—pioneer settlement. Base map the same as in Fig. 1.

mercial, and political adjustments to the new environment now make their appearance. The natural features of the environment do not seem to lose any of their original power or suggestiveness in place-naming but are rather supplemented by additional classification of names growing out of the diversified cultural and commemorative interest of the incoming settler. This is reflected on the original Federal survey plats of 1827-34 and subsequent maps.

Location Derivation. Every frontier settlement presents the problem of isolation. Circulation within the local region and contact with established communities on the outside thus are of primary concern to any new settlement. And so it came about that one of the prairies of Porter County was named Twenty-Mile Prairie because "as an old settler facetiously said, it was 'twenty miles from anywhere'—meaning, of course, that it was twenty miles (or some multiple of twenty) from the nearest trading post, being twenty miles from Michigan City and LaPorte, and forty miles from Chicago."[15]

Much greater significance attaches to this characterization of this prairie when we realize that the lake plain between the Valparaiso moraine and the Lake Michigan ports in those days constituted almost an impassable marsh for a large part of the year, requiring more days then than it takes hours today to reach Chicago or Michigan City.

Water Derivation. At this early period the site of Michigan City seems to have been thought of as the most strategic place for port development on Lake Michigan. The circumstances of its naming and that of the famous road extended from Indianapolis to the lake suggest this. "Michigan City bears the distinction, almost unique, of having been in existence in design long before it was ever laid out even on paper. It was quite natural that out of the familiar mention among the statesmen of the road to Lake Michigan and the city of Lake Michigan there should grow the names now borne by the city and the road, and that the names should be in use before either came into being. The earliest mention of such a city occurred in the course of the discussion of the boundary question."[16]

Lake County also derives its name from its position on Lake Michigan.

Biota Derivation. LaPorte County came to be named after the prairie-timber pattern in the vicinity. "The door" effect consisted of "a natural opening through the timber from one prairie to the other, where 'Door Village' now stands."[17]

The charming "door" village situation on the moraine may be said fairly to characterize the general settlement pattern of the Calumet pioneer who almost always located his cabin on the edge of a beautiful

[15] Goodspeed, W. A., and Blanchard, Charles, *Counties of Porter and Lake*, F. A. Battery and Co., Chicago, 1882, p. 192, quoting Hyde.

[16] Oglesbee, Rollo B., and Hale, Albert, *History of Michigan City, Indiana*, Edward J. Widdell, 1908, p. 69.

[17] *Illustrated Historical Atlas of LaPorte County, Indiana*, Higgins, Belden & Co., Chicago, 1874, p. 3.

grove overlooking the adjacent prairies. These prairies opening onto one another through corridors in the timbered tracts were among the first regional landscapes to be named by the settlers, as, for example, Horse Prairie, Hog Prairie, and Dormin ("maize") Prairie. Others were named for early settlers as indicated below. Groves, the preferred sites of early settlement, similarly came to be named by the pioneer settlers (see classification table, Fig. 5).

What was probably the first political designation of any part of the northwest Indiana region was "Oakland County," a name given by Solon Robinson, the "dean" of Calumet pioneers, as descriptive of most of the timber of the area. A check on the Federal surveyor's contemporary records (1927-34) reveals the accuracy of this observation, oak constituting the dominant genus in the tree consociations of the area. But the name did not survive. On the other hand, Pine Township, in northeast Porter County, may be said to memoralize a one-time dense conifer timber tract in this section of the lake shore dune country. Our field survey of the timber cover of this area today hardly suggests a one-time flourishing pine-lumbering industry in this region. However, the toponomy in this case was found to represent a helpful hypothesis of the one-time commercial importance of this type of timber in constructional projects in the Chicago-Calumet area.

Physiographic Derivation. In the northwest quarter of the Calumet area, several conspicuous island-like landforms rise above the otherwise relatively featureless plain. The settlement of Blue Island on one of these thus came to be named from its "island" site (high and dry above the marsh lands), and the fact that settlers were impressed by the "blue" appearance of its vegetative cover as seen from a distance.

Imported Nomenclature. Certain maps naturally may constitute valuable source material of sequent occupance toponomic geography. Such a map, for example, is Colton's Map of Indiana which is highly useful in checking on the first urban settlements of the Calumet region, since the date of its publication, 1853, fits well into this period's inventory of place names. Such a map may help to explain a geographic problem. For example, if we look at a present-day map and see the pretentious name "Liverpool" applied to a railroad junction of but a few houses at the confluence of Deep River with the Little Calumet, we may surmise that it represents only a mere whimsical circumstance of no geographic significance other than suggesting that the namer was probably an immigrant from Liverpool, England. But when we see in addition such names as Manchester, Sheffield, City West (site of modern Waverly), and Indiana City (site of the old now obliterated mouth of the Grand Calumet River), we come to realize that these names regionally considered together, suggest the aspirations of an ambitious people which foresaw in the strategic position of the Calumet area the capacity to develop into one of the largest industrial and commercial communiites in the nation—as it eventually did.

However, all these "cities," vying with Chicago for mercantile supremacy, and platted and planned by fantastic promotion schemes, hardly advanced beyond the blueprint stage. In fact, all, except Liver-

pool, disappeared entirely from the map. Liverpool, the sole survivor, then, may be regarded as a philological fossil geographically expressive of the dominating speculative spirit of the Calumet resident, which in time attained full fruition in a neighborhood community—the Gary-Chicago region.

Equally historic is the city of Crown Point, originally called Lake County Court House. It was the first town in Lake County to be surveyed and platted (1840), and has served as the county seat of Lake County ever since it was founded. It was named for Crown Point, New York, by Solon Robinson, a Connecticut Yankee, and toponomically suggests one of the chief sources of the early Calumet settlers—the New England-New York area.

Descriptive and Commemorative Names. The appearance of names of prairies on the original Federal land survey plats suggests that already at this early period (1827-1834), before the public sale of governmental lands acquired by final treaty in 1832, squatters had settled on the Pottawatomie's Calumet domain. The Twenty-Mile Prairie mentioned on page -- is such an example. The Prairie toponomy thus is geographically significant in several ways: 1. it supplies, as already stated, evidence of squatter settlement, 2. it represents the first step, we might say, in the development of concepts of the regionalization of an area which, in a politically unorganized pioneer society, naturally enough is based on the distinguishing features of the physical landscape more than on anything else.

It is to be expected also that toponomy of this period will feature names derived from the earliest settlers in the region. An example is Morgan Prairie "named for Isaac Morgan who was one of the first settlers upon this beautiful plain, in what is now Washington Township."[18] Another is Robinson Prarie honoring the chief of squatters.

Much of the Calumet prairie in the pioneer days was too wet for settlement, and far-flung marshes on the lake plain, between the east-west ridges of beach-dune sand, made approach to Lake Michigan from the south extremely difficult. This landscape phenomenon doubtless explains in part the failure of the "phantom" river and lake port sites to establish a metropolitan community at the "head" of Lake Michigan in competition with the Fort Dearborn settlement at Chicago. One of these marshes was Cady Marsh, named after Jack Cady who operated a tavern for stagecoach travelers.

In 1832 the United States government concluded the purchase of Pottawatomie lands with the exception of a few Indian reservations. In the succeeding year the government established a land office at LaPorte, and in 1839 offered the land for sale to the squatter and other incoming settlers. The Fort Dearborn-Detroit Trail had been completed in 1833. These events set the stage for organized political settlement and the resulting county, township, and town nomenclature. Most of the political geography toponomy is commemorative in character.

[18] Goodspeed, *op. cit.*, p. 185.

The county names of Cook and Will are patronymics respectively for Daniel P. Cook, a former Illinois statesman, and Dr. Conrad Will, a delegate to the Illinois first constitutional convention.

Porter County was named in honor of Commodore David Porter, who commanded the Essex during a battle near Valparaiso, Chile, in the War of 1812-14. It is interesting to note that the incident of this battle furnished three names in one association: Porter, for the county, Essex for a township, originally by that name, and Valparaiso for the county seat.

Loyalty and patriotism are reflected in such names as Union Township, Washington Township, and Liberty Township—all of Porter County.

Though corporate-town development in the Calumet region is not really a political geography feature of this period, the names of a number of corporate urban communities of the next period were already currently applied to individual or group pioneer settlements started in this period. This early homestead or village settlement toponomy memorializes "seniority" of a settler or preeminent distinction of a local or a national figure. We shall here refer to a few of historic prominence. Tolleston, representing a sort of "fossil" ancestor of our modern steel center of the midwest, Gary, was named after George Tolle, a pioneer who owned extensive tracts of land in the vicinity.[19] Among other pioneer settlements included in the same category of this period belong Dolton, near a strategic toll bridge across the Little Calumet; Hobart, aspiring to become the lumbering headquarters of this area for Chicago; and Merrillville, early site of a prominent Indian village and one of the stopping points of the "forty-niners" on their trek to the gold fields in California. Place names of settlers may also tell us something about the distribution and character of the rural settlement pattern. Such is the service rendered by Rees' map of northeastern Illinois (1851). Here we find, for example, in Bloom Township of Cook County, more than a dozen individual farmsteads whose names, like Butterfield, Caldwell and Chatman, suggest almost an exclusive English or Yankee community.

The Geographic Toponomy of Primary Commercial Agriculture, Urban Industry, and Earth Science

Market- and Factory-Town Nomenclature. By 1850 county organization of the Calumet area had been completed, incluhing a number of township divisions. And so the newly introduced toponomy henceforth is concerned chiefly with the naming of an increasing number of townships and urban communities which sprang up largely in response to improved methods of transportation, marketing, and manufacturing.

In 1848 the first plank road was built into neighboring Chicago. In the same year, trains on the Illinois Central Railroad crossed the west

[19] Lester, J. William, "Pioneer Stories of the Calumet," *Indiana Magazine of History*, Department of History, Indiana University, Vol. 18, No. 2 (June, 1922), p. 169.

end of the Calumet to Chicago. Four years later the Michigan Southern and Northern Indiana Railroad, now aptly named the Lake Shore, gave east-west passage connecting the eastern Calumet area with Chicago. These were followed rapidly by additional roads. The new transportation facilities in turn opened up new markets for the farmer. Small railroad post offices and passenger stops, elevator sidings, and community produce and trading stations multiply rapidly and are named chiefly after settlers, as is indicated by such names as Clarke Station and Miller Station; Crisman and Hageman (Porter); Merrillville, Schererville, Hessville, and Holmesville.

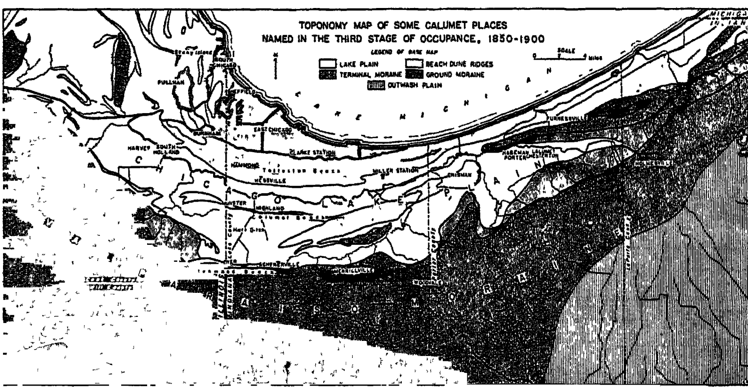

Fig. 3. The geographic toponomy of primary commercial agriculture, urban industry, and earth science. Base map as in previous figures.

Improved transportation also made possible a limited industrialization of the area. This is perhaps best symbolized by the city of Hammond whose name memorializes the first large industry of the area, the former George H. Hammond Packing Company. As one writers notes, "The 'big industry' of the county up to 1884, aside from agriculture and the big trunk line railroads, was the state line slaughter house which was established at Hammond in 1869. It did a big business in the killing of all kinds of meat animals and in shipping meats, with their patented refrigerator process, to eastern United States and to Europe. In 1901 the slaughter house burned and the company then moved its forces to the Union Stock Yards in Chicago."[20] This new site, only a little over fifteen miles distant, has become the greatest meat-packing center of the world.

The name of the town of Pullman, founded in 1880, originated under circumstances similar to that of Hammond. Here George M. Pullman perfected the so-called "Palace" car, or "Pullman," which has revolutionized passenger service the world over.

The names of the neighboring industrial-commercial communities of Burnham and Harvey are likewise patronymic in character.

[20] Woods, Sam, *Still a Pacifist,* 1934, p. 283.

The linked expansion of Chicago south and east finds toponomic expression in new corporate terms derived from Chicago itself, as, for example, South Chicago, Illinois, and East Chicago, Indiana.[21]

Geology and Associated Town Nomenclature. We have observed that in the initial occupance of the fundament, the Indian-French stage, the toponomy reflected man's thinking and acting in forms almost exclusively of single natural elements in the environment. In the succeeding pioneer stage, the introduction of a prairie-marsh nomenclature signified the arrival of an areal geographic concept of environmental elements. But now as a distinguishing feature of the close of this period and continuing into the next, we meet with the origin and first applications of a toponomic nomenclature expressive of both space and time concepts of the Calumet landform features.

Moreover, the region now begins to take on an inter-regional and national significance in scientific literature through the works of Chamberlin, Wooster, Leverett, Blatchley, and others. Monograph 53, by Leverett, of the United States Geological Survey, contains a classical treatment of glacial features and associated phenomena of the area and refers to the origin of some of the leading physiographic place names.

The name "Chicago Lake Plain" well characterizes the area in which lie the master drainage lines of the Calumet rivers. It denotes at once the present geographic location and physiognomy and postulates the ancestral glacial lake "Lake Chicago." The tributaries from the south draining into the Little Calumet descend from the bordering terminal moraine, called the Valparaiso moraine. The moraine was so named by Wooster because the city of Valparaiso is located on a very prominent portion of the moranic system in northwestern Indiana.[22]

Physiographic relicts of the various recessional shoreline stages of Lake Chicago in the form of beach-dune ridges are named in two instances on the basis of town association. Thus the oldest, highest, and outermost beach, the Glenwood Beach, "received its name from the village of Glenwood. . . . The name has been selected (1) because the beach is especially well developed at that village, and (2) because, being near the state line of Indiana and Illinois, the name will be familiar to residents of either state."[23]

The next lower lake level beach, the Calumet Beach, "throughout much of its course in Indiana follows the south border of Calumet River, and because of this close association the name Calumet seems appropriate."[24]

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[21] The term Chicago is Indian and is variously held to denote the name of an Indian chief, or a "place of the skunk" or a "place of wild onions" (same Indian stem). Jacob Piatt Dunn in his "True Indian Stories" (Sentinel Printing Co., Indianapolis, Ind., 1909) contends for the correctness of the last mentioned, since, as he points out, the earliest French chroniclers referred to the Chicago River as "Garlick Creek." It appears beyond question that the wild onion once flourished on the Chicago Lake Plain, now the seed bed of the most intensive onion-set culture in the United States.

[22] Leverett, Frank, *Monograph 38,* United States Geological Survey, Washington, D. C., 1899, p. 339.

[23] *Ibid.,* p. 428.

[24] *Ibid.,* p. 442.

The latest and lowermost of the fossil beaches is called Tolleston Beach after the town of Tolleston (near Gary) where it is exceptionally well developed.

The transportational and demographic significance of the ancient shore line beach-dune ridges parallel that of their geologic history. Before ditching and tiling, the Chicago Lake Plain was almost one continuous marsh except for sandy ridges and islands and a few other slightly elevated tracts. The east-west trend of the main ridges were chosen for the chief routes of travel, and so, from the earliest times down to the present, the arterial travel and settlement patterns for a long time coincided almost one hundred per cent with these "fossil" beaches. These physical-cultural associations are toponomically recognizable in the name "Ridgeroad" for the highway following in the main the Calumet Beach and the name "Highland" for one of the "shoe-string" (*strassendorf*) rural-urban settlements on the same ridge. It is of Dutch origin.

Munster, another one of the "shoe-string" settlements, strung for five miles along Ridgeroad, from Lake County into Cook County, was named for an early settler, Jacob Munster, who, together with other Dutch immigrants, "came to the site in 1855 from Rotterdam, Holland."[25] But the name "Munster" does not simply commemorate an early Dutch family; it stands for a whole colony of Hollander-Americans. In fact, this place name may be said to symbolize an environmentally adjusted economy based on floral and truck farming on low lands not much unlike that of the country from which the Dutch emigrated. This garden culture, whether by the Dutch or other nationalities, is characteristic of the whole west end of the Calumet area, which includes still another Dutch settlement, the South Holland community.

The Geographic Toponomy of the Modern Calumet Environmental Complex

Names Associated with Specialized Industries and Farming and Regional Conurbanization. Though the impetus to modern facilities of transportation and industrial development occurred already near the close of the previous period, it was not until near the opening of the twentieth century that the whole Calumet area became intimately identified with the Chicago metropolitan district. As one writer points out, "Exclusive of Hammond, the total population of the region now occupied by Gary, East Chicago, and Whiting was, in 1888, not more than 800. Not until the latter part of that year, when the Standard Oil Company of Indiana bought a large acreage on the present site of Whiting, did the Calumet begin to change its character."[26]

We now see evidence of chorographic contiguity between the Calumet, as the corridor for the road and rail trunk line traffic Chicago bound, and the Calumet, as the conurbanized head of the Lake Michigan region. The suburban communities south and east of Chicago, once separate urban units like Burnham, Pullman, South Chicago, Whiting, East

[25] Works Progress Administration, *op. cit.*, p. 123.
[26] *Ibid.*, p. 25.

Chicago, Calumet City, Hammond, now form a fused metropolitan mosaic. Thus the state line and corporate units have all but lost their geographic distinction (example: Hammond, Indiana, and West Hammond (Calumet City), Illinois).

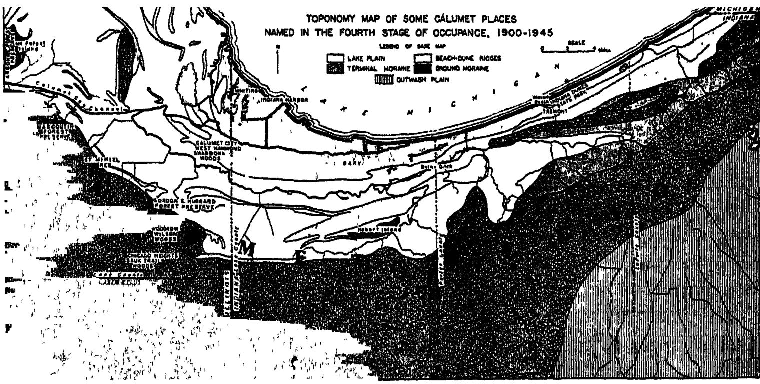

Fig. 4. The geographic toponomy of the modern Calumet environmental complex. Base map as in previous figures.

The name Calumet Region as a suburban area of Chicago now appears in cartographic nomenclature, and a resident most anywhere in the Calumet is a potential commuter of Chicago.

As the cities of Hammond and Pullman in the previous period memorialize founders of the great meat-packing and parlor car industries, so the city of Gary honors the founder of the steel center of the middle west, Judge Elbert H. Gary, chairman of the finance committee of the United States Steel Corporation. The first steel plant had been built at Indiana Harbor (East Chicago) by the Inland Steel Company in 1901. Now in 1906 ground was broken for the first steel mills at Gary. Founded in 1906 with a population of 1,000, the city today claims a population of around 115,000 representing fifty-five different nationalities.

A train wreck was responsible for the name of another spot destined to share the fame of the preceding cities, namely, Whiting's Crossing, named after one of the engineers or conductors involved in the accident. Abbreviated to "Whiting" by the Standard Oil Company, this town, distinguished for its row upon row of gray squat tanks, is as distinctive a Calumet industrial landmark as are the steel mills of Gary and Indiana Harbor.

Reclamation Nomenclature. But the phenomenal growth of settlements and expansion of agriculture and industry in the Calumet was made possible only by artificial drainage—canals, ditches, straightened rivers, and tiling. Ordinary drainage ditches often bear the names of the first signers of drainage petitions.

owned 1,200 acres of marshland on the site of Gary and "originated the idea of reclaiming the Pontine-like marshes (20,000 acres) of the region."[27]

The naming of the earlier Hart Ditch, constructed in the vicinity of Dyer in the early nineties, was likewise identified with the owner of 17,000 acres of land in the vicinity, namely A. M. Hart.

Recreation Nomenclature. Place nomenclature identifying outdoor recreational features is as reflective of human characteristics and interests as are those of industrial and commercial development. In the early stages of human occupance little attention is given to a toponomic recognition of recreation landscape units. The need for distinguishing, classifying, and naming such sites and features arises from an increasingly intensified use of restricted areas set aside for this purpose in competition with other land uses. This is particularly true in a region like the Calumet whose lake shore position presents an equally phenomenal attraction to the recreationist and the industrialist. Here, extending eastward from Gary, are the famous Indiana sand dues,[28] unique alike as a metropolitan playground and a naturalist's laboratory.

Waverly is the site of the Indiana Dunes State Park which preserves the best developed dune topography. Seeking the source of this name leads one to the discovery of a change in the political geography of the area, this beach, now in Porter County, having been once a part of Waverly Township of La Porte County.

Like many of the feature names of other romantic scenic spots in America, Calumet duneland toponomy combines the fantastic and mystical with the descriptive and the commemorative. This is well illustrated in the naming of the loftiest part of the dune country in the Dunes State Park, where the early pioneers personified the contiguous three highest dunes by calling them "The Three Sisters."[29]

In accordance with the tendency of the present age to multiply as well as to romanticize recreation toponomic features, The Three Sisters were topographically classified as mountains, and, from west to east, were separately dubbed Mt. Tom, Mt. Holden, and Mt. Green. The name "Mt. Tom" is based on the tradition "that a sailor whose name was Tom was buried on the top."[30]

Mt. Green was named to memorialize a pioneer who operated a hotel near Tremont, a station whose French name suggests its proximity to the "three mountains" just mentioned. It was later changed to Mt. Jackson in honor of Governor Ed Jackson whose office secured tax legislation for the purchase of the 2,200 acres comprising the modern Indiana Dunes State Park.

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[27] Works Progress Administration, *op. cit.*, p. 70.

[28] " 'Dune' comes from the term 'dun' which is of Celtic origin; 'dun' meaning 'hill.' "—E. S. Bailey, *The Sand Dunes of Indiana*, A. C. McClurg and Co., 1917, p. 35.

In earlier days the dunes were known as 'sand knobs.'

[29] Brennan, George A., *The Wonders of the Dunes*, The Bobbs-Merrill Co., Indianapolis, 1923, p. 168.

[30] Bailey, *op. cit.*, p. 159.

It is most fitting that one of the dunes, the middle one, should honor a Mr. Holden, the first president of the Prairie Club in Chicago, which organization is reputed to have made the greatest single contribution to the modern popularization of the Dunes.

Thus the toponomy of the three dominant dunes together with the name "Tremont" may be said dramatically to epitomize a number of the elements of the region's sequent occupance as to tradition, history, topography, and settlement.

The west end of the Calumet region, in close proximity to Chicago, abounds in public "woods" or "forest preserves." Among the varied motives reflected in the place names, several classes stand out. One class is reminiscent of the Indian-fur trader occupance (Ex. Mascoutin, Sauk Trail, Shabbona, Gordon Hubbard); another recalls First World War associations (Ex. Argonne, St. Mihiel, Woodrow Wilson).

Place Name Changes

Place name changes have their significance as do the names themselves. At times, the meaning of a place name may persist, but its linguistic form may change in accordance with the several sequent occupance stages.

Thus the creek at Michigan City was first called Me-eh-way-se-be-way by the Pottawatomie to signify "a creek along which there was a trail."[31] The subsequent French occupance of the area is revealed by the translation of the Pottawatomie name to "Riviere du Chemin" which appears on early French maps, "as early as the Franquelin map of 1688."[32]

Some toponomists decry the fact that not more Indian place names have been retained in our descriptive or commemorative nomenclature. We can hardly blame the French for changing this one. But the French translation in turn did not fare much better than the Indian name. However otherwise euphoneous the new French name "Riviere du Chemin" sounded, this pronunciation also proved too much for the American pioneer who came to refer to the stream phonetically as "Dishmaw, Dismaugh, Dysman, and the like." And so the "river by the trail" eventually was simplified to "Trail Creek."[33]

Change in the name of one of the towns in the Calumet area reveals an interesting example of geographic place association. "Valparaiso, originally called Portersville, was organized in 1836 by the Portersville Land Company to secure the location of the Porter County seat. In 1836 a party of sailors stopped overnight at Hill's Tavern and after entertaining the natives with stories, one suggested that since the county was named for Commodore David Porter, who was in command of the Essex during a battle near Valparaiso, Chile, it would be appropriate to name the county seat after that town. The suggestion was accepted.[34]

[31] Dunn, *op. cit.*, p. 308.

[32] Oglesbee, *op. cit.*, p. 6.

[33] There is additional toponomic evidence that there was a protest against retaining even such a beautiful sounding name as La Porte. When its meaning discovered, someone remarked why not simply call the place, then, "The Door."

[34] Works Progress Administration, *op. cit.*, p. 119.

A change in name indicates a change either requested by the postal authorities, or dictated by a change in toponomic taste, or prompted by some new social, commercial, political, or other motive. Some places have had their names changed several times—Otis, as many as four.

GEOGRAPHIC CLASSIFICATION OF REPRESENTATIVE CALUMET PLACE NAMES

Past And Present

NAMES OF THE NATURAL ELEMENTS OF THE ENVIRONMENT

PLACE NAMES	Motive based upon Physical Geography, Chiefly Descriptive: Location	Size & Shape	Geomorphology	Lithology	Hydrography	Biota	Motive based upon Human Geography, Chiefly Commemorative: People: Resident	People: Non-Resident	Place	Culture	Sentiment
LANDFORMS											
1 BEACH-DUNE FORMATIONS											
Calumet Beach					•						
Glenwood Beach									•		
Tolleston Beach									•		
2 DUNE FORMATIONS											
Furnessville Blowout									•		
Mound Valley			•								
Mt Holden			•					•			
Mt Jackson			•					•			
Mt Tom			•				•				
"Sand Knobs"			•	•							
3. "GLACIAL" FORMATIONS											
Chicago Lake Plain					•				•		
Valparaiso Moraine									•		
4. LAND "ISLANDS"											
Blue Island									•		
Hobart Island							•				
Mt Forest Island			•			•					
Stony Island				•							
NATURAL VEGETATION FORMS											
1. GROVES											
Beebe's Grove							•				
Gooding's Grove							•				
Pleasant Grove											•
Plum Grove						•					
Twenty-mile Grove	•										
2. PRAIRIES											
Door Prairie						•					
Dormin Prairie						•					
Hog Prairie						•					
Horse Prairie						•					
Morgan Prairie							•				
Oakland Prairie						•					
Robinson Prairie							•				
Twenty-mile Prairie	•										
HYDROGRAPHIC FORMS											
1 CREEKS, RIVERS, SPRINGS											
Calumet River					•	•					•
Deep River		•									
Fort Creek										•	
Grand Calumet River		•									
Little Calumet River		•									
Salt Creek				•							
Trail Creek										•	
2. LAKES											
Berry Lake							•				
Calumet Lake					•						
Cedar Lake						•					
Lake George							•				
Lake Michigan		•									
Long Lake		•									
Pine Lake						•					
Round Lake		•									
Stone Lake				•							
Wahob Lake							•				
Wolf Lake							•				
3. MARSHES, SWAMPS											
Cady Marsh							•				
Cowles Swamp								•			
Page Swamp							•				
Tamarack Swamp						•					

NAMES OF THE CULTURAL ELEMENTS OF THE ENVIRONMENT

PLACE NAMES	Motive based upon Physical Geography, Chiefly Descriptive: Location	Size & Shape	Geomorphology	Lithology	Hydrography	Biota	Motive based upon Human Geography, Chiefly Commemorative: People: Resident	People: Non-Resident	Place	Culture	Sentiment
ETHNOGRAPHIC AREAS											
Mascoutins						•					
Pottawatomie											•
INDIAN RESERVATIONS											
La Frombois							•				
Pettier							•				
GEOGRAPHIC AREAS											
Calumet Region					•						
"Quadoche"							•				
Ten-Mile Purchase		•									
POLITICAL AREAS											
1 COUNTIES											
Cook County							•				
Lake County	•				•						
La Porte County						•					
Porter County								•			
Will County								•			
2. TOWNSHIPS											
Bremen Township									•		
Cass Township								•			
Center Township	•										
Essex Township										•	
Frankfort Township									•		
Jackson Township							•				
Liberty Township											•
Morgan Township						•					
Pine Township						•					
Pleasant Township											•
Portage Township									•		
Ross Township							•				
Springfield Township					•						
St. Johns Township									•		
Union Township											•
Washington Township								•			
Winfield Township								•			
RECREATION AREAS											
Argonne Forest Preserve									•		
Gurdon S. Hubbard Forest Preserve								•			
Indiana Dunes State Park	•										
Mascoutin Forest Preserve							•				
Sauk Trail Woods										•	
Shabbona Woods								•			
St. Mihiel Forest Preserve									•		
Woodrow Wilson Woods								•			
SETTLEMENT FORMS											
1. FARMSTEADS											
Butterfield							•				
Caldwell							•				
Chapman							•				
2. VILLAGES, TOWNS, CITIES											
Abercronk									•		
Blue Island			•			•					
Baillytown							•				
Bigelow Mills							•			•	
Burnham								•			
Calumet City					•						
Chesterton									•		
Chiqua's Village							•				
Chicago						•					
Chicago Heights			•						•		
Clarke Station							•			•	
Crisman							•				
Crown Point									•		
Dolton							•				
Dyer							•				
East Chicago	•								•		
Frankfort									•		
Furnessville							•				
Gary							•				
Hageman							•				
Hammond							•				
Harvey								•			
Hessville							•				
Highland			•								
Hobart							•				
Holmesville							•				
Indiana City									•		
Indiana Harbor					•				•		
Ish-kwon-dem						•					
La Porte						•					
Liverpool									•		
Manchester									•		
M-dah-min						•					
Merrillville							•				
Michigan City					•						
Miller Station							•			•	
Munster							•				
New Buffalo									•		
Palmer							•				
Pullman							•				
Robertsdale							•				
Schererville							•				
South Chicago	•								•		
South Holland	•								•		
Tamarack Station						•					
Thornton								•			
Tolleston							•				
Tremont			•								
Valparaiso									•		
Wanatah							•				
West Hammond	•								•		
Wheeler								•			
Whiting								•			
Woodvale							•				

Fig. 5.

Summary

Toponomy is the science of place names as to the origin, meaning, classification, and use. Every place name is said to have some significance. To the geographer, many place names may have little or no systematic or regional relationship value, yet nearly every region seems to have some names which reveal a number of characteristics of its physical environment or reflect something about the character of its people.

The systematic study of place names, then, in chorographic association with the physical and cultural elements of a region, may prove very helpful in relating and integrating geographic phenomena. Particularly is this true in a sequent occupance study in which the "philological fossils," as relicts of the landscape, may be instrumental in reconstructing the historical-geographic reality of a region.

As applied to the Calumet region, sequent occupance toponomy reveals a phenomenal diversity and continuity of application of the name "Calumet" in such a way as to indicate a growing consciousness of the integral character of the region designated by this name.

As we would expect in the Pottawatomie-French occupance stage, place naming is identified chiefly with waterways (ex: "Lake Michigan"), the natural means of aboriginal circulation. The place names in nearly all cases are descriptive of hydrographic forms or land features useful in topographic analysis.

The toponomy of the next period reveals the isolation and communication difficulties inherent in squatter pioneer settlement (ex: "Twenty-Mile Prairie"). Natural forms of the environment play an important role in suggesting place names for the newly established settlements, but a rapidly increasing number of commemorative names of both people and places make their appearance (ex. "Porter"; "Valparaiso"). Among these are imported names which impress us with the geographic sources whence the imigrants came, and, what is more important, the ideas that some had brought with them (ex: "Liverpool"; "Manchester").

Names commemorating people and places seem to be in the ascendency during the next period of pioneer commercial and industrial development. The names of locally distinguished citizens are given to a rapidly growing number of urban settlements ("Hammond"). Certain settlements—Glenwood, Tolleston, and Valparaiso—distinguished themselves to the outside world by transferring their names to historic geologic formations they exhibit to advantage.

The final or present period features a complexly mixed toponomy identifying competing land uses for residence, agriculture, industry, reclamation, and recreation. Names are mostly of the commemorative type, the study of which personages they represent is not entirely without geographic value since such characters often furnish personal clues to conditions of rural and urban development (ex: Burns' Ditch reclamation; Gary steel industries).

Thus the Calumet study illustrates how toponomy may be usefully integrated with the topography for a complete chorographic synthesis.

HISTORY OF SCIENCE

Chairman: C. O. Lee, Purdue University

Mr. John S. Wright was elected chairman of the section for 1945.

The type concept in modern biology. Theodor Just, University of Notre Dame.—The typological approach to morphological problems is as old as morphology itself. Yet it is repeatedly rejected at the present time as the "old" morphology despite the fact that biochemists, geneticists, ecologists, and others frequently use the same approach. The typological approach is therefore a fundamental one, which is applicable in all fields and at any time.

A historian views science. Louis M. Sears, Purdue University.—An address presented to the general session of the Academy.

A critique of science. Carroll D. W. Hildebrand, DePauw University.—An address presented to the general session of the Academy.

A Century of Odonatology in Indiana

B. ELWOOD MONTGOMERY, Purdue University

Although probably not as familiar to the average citizen as bees, beetles, butterflies, and a few other common insects, members of the order Odonata appear to be rather well known to the ordinary Hoosier, and are especially noted by those who frequent the banks of streams or the shores of lakes. In Indiana the most usual common names for an insect of this order are dragonfly, snake feeder, and snake doctor. Darning needle, Devil's darning needle, spindler, and, for the Zygoptera, damselfly, are used less widely. The widespread use of the name dragonfly was shown some years ago when a class in Introductory Entomology at Purdue University was given a recognition test on insects at the first meeting of the class. Dragonflies were named correctly by more students than were any other insects, even butterflies.

Without doubt, the exact application of these names is somewhat hazy, even considerably confused, in the mind of the average Hoosier. According to Walton (1922) Madison Cawein, the Kentucky poet, who wrote more than a dozen complete poems on insects, "spoiled a perfectly good poem on the 'ant-lion' by confusing the insect with the dragon-fly, when he could instantly have settled his doubts in the matter by referring to any good, general work on natural history." However, Cawein called this poem *Old Snake Doctor,* and he did write a poem, *Dragonflies,* showing a rather extensive and accurate knowledge of the habits and life history of the Odonata.

Reference to dragonflies occur in the lines of many poets but I know only one reference to snake feeder. This is found in that well-known poem, *The Old Swimmin'-Hole,* by our own James Whitcomb Riley,

> "And the snake-feeder's four gauzy wings fluttered by
> Like the ghost of a daisy dropped out of the sky,
> Or a wounded apple-blossom in the breeze's controle
> As it cut acrost some orchurd to'rds the old swimmin'-hole."

Riley also knew these insects as dragonflies, and he knew something of the habits and structure of different species. He referred to the resting habits of some zygopteron in *The Brook Song,*

> "Little brook—sing a song
> Of a leaf that sailed along
> Down the golden-braided center of your current swift and strong,
> And a dragon-fly that lit
> On the tilting rim of it
> And rode away and wasn't scared a bit."

He described the shuttle-like flight of some hawking form in *With the Current,*

> "Back and forth, to and fro—
> Flashing scale and wing as one,—
> Dragon-flies that come and go,
> Shuttled by the sun."

In *The South Wind and the Sun,* he referred to the metallic appearance, the hard exoskeleton, and the hurried flight of some aeshnid (or cordulid?),

> "Till the dragon-fly, in light
> Gauzy armor, burnished bright,
> Came tilting down the waters
> In a wild, bewildered flight."

The history of the scientific study of the Odonata in Indiana covers a period of more than 100 years. The first paper listing records of dragonflies from the state, which was also the first paper on the Odonata published in America, was Thomas Say's *Descriptions of North American Neuropterous Insects, and Observations of Some Already Described.* This paper was probably written only a short time before the death of the author (October 10, 1834); it was read before the Academy of Natural Sciences of Philadelphia, July 12, 1836, but was not published until 1839.

Of the 17 species listed from Indiana by Say, 16 were described as new, but two of these, *Aeshna multicincta* [= *Epiaeschna heros* (Fabricius)] and *Lestes basalis* [= *Hetaerina americana* (Fabricius)], were synonyms. No locality records beyond the statement "Inhabits Indiana" were given, except for *Gomphus fraternus* which, although listed from "North America" was noted to be "common in June on the banks of the Wabash." A list of 17 species does not seem very impressive when compared with our present state list of 140 species, and one may well wonder how Say missed such common species as *Argia violacea, Enallagma civile, Calopteryx maculata* (which he described from Massachusetts under the names *materna* and *opaca*), and many others. Oddly enough, however, his list included three species—*Cordulegaster obliquus, Somatochlora linearis,* and *Neurocordulia obsoleta*—which are now considered as very rare in Indiana; *N. obsoleta* has not been taken in Indiana again. Without doubt, much change had been effected in the Odonate fauna of the state during the 60 or more years following Say's collecting before another great Indiana naturalist began his intensive study of dragonflies. As the latter has observed, "In these sixty-five years . . . the State had passed from a wilderness to cultivated lands. Where the farmer as a boy caught cat-fish and snapping turtles, he plowed corn as a man. The smaller streams became tile ditches, the primitive forests, fields and pastures. What changes took place in the original plant and animal inhabitants of the State are known very meagerly even for the most conspicuous forms. The passing of the obscurer has not left a trace. Of the wild turkey and the deer we know something, but who has concerned himself with the extinction of an orchid, or the loss of a dragonfly?" (Williamson 1912).

Thomas Say was a general collector and probably made no special effort to secure specimens of the Odonata. Our present set of records is the result of innumerable hours of intensive search, extending over a period of about 45 years, mostly by Edward Bruce Williamson, the most indefatigable and skilled naturalist who ever worked with the Odonata.

Furthermore, very little was known of the group in Say's time; none of the classics of Odonatology had been written. Although de Selys had published his first paper in 1831, his second did not appear until three years after Say's death. His third appeared in print the same year Say's paper was published, 1839, which was also the date of Hagen's first contribution to Entomology, and of the appearance of Burmeister's Handbuch. Rambur's Nevropteres was published in 1842.

The science of Odonatology may well be said to have had its origin at this time (1839-1842), as previous authors had given dragonflies only causal attention in general entomological lists or discussions. Linnaeus in the twelfth edition of the *Systema Naturae*, the last published during his life, described only 20 species of Odonata, placing all of them in the genus Libellula of the order Neuroptera. Fabricius in his *Entomologia Systematica* and supplements increased the number of species to 75 and added two genera. Other authors, as a rule, had confined their discussions of the Odonata to a compilation of the works of Fabricius, enriched occasionally with notes on development and life history borrowed for the most part from DeGeer and Reaumur. Burmeister described 159 species, arranged in six genera, Rambur more than 360 in 33 genera. Even these authors considered the Odonata as a family of the Neuroptera, and their discussions of the group were parts (although in the case of Rambur much the greater part) of more extensive works on that heterogeneous Linnean order.

The delay in the publication of Say's paper until 1839 was very unfortunate because in that year Burmeister named eight of the species which Say had named. Since the exact date (month and day) of publication of neither paper is known, it cannot be determined which set of names has priority. Hagen (1890) and Calvert (1906) discussed this matter, and Hagen insisted that Say's names had precedence because his paper had been read publicly in 1836. Although there is no basis in the Rules of Nomenclature for Hagen's contention, Calvert and other authors have continued to use such of Say's names (in preference to those of Burmeister) as are not invalid for other reasons.

After the publication of Say's paper, it was 56 years before another paper dealing directly with Indiana Odonata appeared. "Indiana was too far west to be visited by the eastern entomologists and too far east to share in the great western explorations of the period." In 1895 Professor Kellicott of Ohio State University prepared a list of 14 species from Turkey Lake (Lake Wawasee), Kosciusko County, based upon collections made by Doctor Eigenmann and his students in July and August of that year. This was published as part of a study of *Turkey Lake as a Unit of Environment, and the Variation of its Inhabitants* (Kellicott 1895).

In 1897 E. B. Williamson, who had been a student of Kellicott, prepared a list of 25 species from Round and Shriner lakes, Whitley County, for the annual report of the Indiana Department of Geology and Natural Resources. In the following year he described a new species *(Ischnura kellicotti)* from this same locality.

During the autumn of 1898, R. J. Weith and Williamson prepared a list of species for the state. This list included 83 species, with dates of capture, localities, and collectors. When this was submitted to Professor Blatchley for publication in the annual report of the Department of Geology and Natural Resources, he requested that it be enlarged to include keys and descriptions of the species listed. Weith turned his notes over to Williamson, who prepared that well-known paper, *The Dragonflies of Indiana*, which was published by Professor Blatchley in his report for 1899 (1900). The original list of 83 species was expanded to include a new species from Wells County *(Enallagma piscinarium)* and 41 species which the author considered as likely to be found in the state with additional collecting. Many, but by no means all, of these have been taken in Indiana since 1899.

Since 1900 numerous additions to the state list of species and much information on the life history, taxonomy, habits, etc., of the Indiana fauna have been published. Weith added four species in a short note published in 1900, and in the following year, as co-author with Needham, he published an excellent account of the life history of *Nannothemis bella* based upon observations made around the lakes of Elkhart County. Williamson published papers containing additions and corrections in the Proceedings of this Academy for 1900 and 1901, bringing the state list to 97 species. C. H. Kennedy published two papers in the Proceedings for 1902, one a list of species from Winona Lake, the other a discussion of certain specific characters of the Indiana species of Argia.

From the time of his first work on Indiana dragonflies until his death in 1933, Williamson continued his collection and study of the Odonate fauna of the state. Some of the results of this work appeared in a number of short papers published in the *Entomological News* (*A Hybrid Dragonfly of the Genus Gomphus*, 1903; *Oviposition of Tetragoneuria*, 1905; *The Known Indiana Somatochloras*, 1912; *Variation in Color Pattern of the Dragonfly Gomphus crassus*, 1919; *Two Days with Indiana Odonata*, 1921; *Indiana Somatochloras Again*, 1922; and *Odonatological Results of an Auto Trip across Indiana, Kentucky, and Tennessee*, 1923). Many other papers, as *The North American Dragonflies of the Genus Macromia*, 1909; *A New Species of Celithemis*, 1910; and *Two New Species of Stylurus*, 1932, which would seem from their titles not to be concerned with the Indiana fauna, are based in no small part upon his Indiana observations and field experiences and list many state records. Of course, Williamson's activities extended far beyond the boundaries of the state and the study of its fauna—he collected in many parts of the United States and Canada and made four collecting trips to tropical America. By collection, exchange, and the purchase of specimens, he built up one of the largest and most representative collections of Odonata in the world; he developed a system of collection, preservation, and study of specimens which has become the standard method of work in Odonatology everywhere; he distributed thousands of specimens to students and museums in many countries. Furthermore, he aided and encouraged many other students by loans of specimens and literature, by entertaining them in his home while they studied his collection, by

suggestions and criticism of their work, and by financial assistance in field work.

At one time or another, or repeatedly, most of the American students of the Odonata—Calvert, Walker, Kennedy, Needham, Hine, Garman, Montgomery, and others—came to study in the Williamson "Bug Room." This was a large upstairs room in the Williamson home at Bluffton; there was a separate stairway to this room and it had no inside connection with the remainder of the house. The collection was arranged in cigar boxes, alphabetically by genera and species in the six great groups of the order—Calopterygidae, Agionidae, Gomphidae, Aeshnidae, Cordulidae, and Libellulidae. These boxes occupied rows of shelves across one entire side of the room. Tables stood along most of the remaining wall space and provided ample room for specimens and literature to be spread out for study. The largest private library on the Odonata, including thousands of titles (book, periodicals, and separata), was housed in cabinets in the room. A most valuable accessory to this library and an essential aid to taxonomic work of the quality found in Williamson's papers was the card index to generic and specific references. This index, on 3x5 cards filling 25 standard file drawers, included an author section and a genera-species section. The latter section, arranged alphabetically in the same manner as the collection, consisted of references to each mention of a genus or species in all papers on the Odonata published after 1890 which Williamson had been able to obtain. It was very complete for the taxonomic literature and for papers on the American fauna. Papers on physiology, (non-taxonomic) morphology, and Old World faunistics were somewhat less completely indexed. The author's introduction to dragonfly literature was obtained by indexing the papers which had appeared during the period from 1918 to 1928 for this index. The original index, now in the Museum of Zoology at Ann Arbor, and a copy in the author's laboratory at Lafayette have been maintained reasonably well up-to-date. Many students have used this index as the basis, or the only source, for all references in monographic studies. Frequently copies of the portions covering particular groups were sent to workers who found it impossible to consult the index in person.

In one corner of the "Bug Room" was a section of shelving with twenty or thirty cigar boxes, each labelled with the name of a student of the Odonata or the curator of a museum which had a collection of Odonata—Sjostedt, Ris, Martin, Calvert, Ruthven, Banks, Navas, Tillyard, Needham, Lucas, etc. Whenever a season's collection was determined and recorded or a generic revision based on specimens accumulated over a period of years was completed, the duplicate specimens were distributed among these boxes. The accumulated duplicates in a box were sent to the individual designated whenever the box became full. The reply "E B" made to a remark concerning the magnanimity and kindness of this practice was typical of the manner in which he always dismissed his acts of helpfulness to others. "Just pure selfishness. I hope to have everyone in the world who has specimens to distribute or exchange, owing me material all the time, so that my collection will receive the first and best of any dragonflies passed out."

However, this practice not only helped to make the Williamson Collection one of the richest and most representative in the world, but also sent Indiana specimens to all of the leading museums and private Odonata collections. This easy availability of Indiana material to students everywhere has led to its frequent use in monographic and other studies. If a complete bibliography of papers on the Indiana Odonata were prepared, it would contain, even if it included only those with direct discussion or mention of Indiana material, contributions by many authors, in several languages, and published in almost every part of the world. The papers which would appear in such a list vary in size from brief notes of a few lines to the monumental 1278-paged *Libellulinen* of Ris.

In 1917 Williamson compiled all Indiana records into *An Annotated List of the Odonata of Indiana*, which included 125 species and indicated the seasonal distribution (by thirds of months) and the counties from which there were records for each. He published a note giving additional records for many of these species and listing another from the state for the first time, in the Proceedings of the Academy for 1920.

In 1924 Williamson influenced the author to take up the study of the Odonata. During that year collections were made in Gibson, Knox, Posey, and Tippecanoe counties, in which no dragonfly collecting had been done previously, and three species new to the state were taken. Records of the 1924 collections and of those made by Williamson during the period of 1921-1924 were published in the Proceedings for 1924 (1925) under the title *Records of Indiana Dragonflies—I*. Since that date similar papers have been published at intervals of one to four years; the latest (1941) which consisted of records for 1937 to 1940 inclusive is the tenth of the series. These papers have included "additions to the state list of species . . . new county records, or captures of rare species already known from Indiana, and important and interesting ecological or descriptive notes on the species concerned." One hundred forty-one species are now known from the state.

In 1928 Williamson went to Ann Arbor, Michigan, as a Research Associate in the Museum of Zoology at the University of Michigan and, at his death in 1933, his "collection, library, indices, microscope, and other equipment were deposited in the Museum, where, as was his wish, they are readily available to any qualified students of the Odonata" (Gaige 1934). Indiana specimens make up no inconsiderable portion of the collection, which contains about 50,000 specimens, representing more than 1700 species, and including almost 350 types. One of the features of the collection which is most delightful to the systematist is the long series of specimens of many rare species, for example, those of gomphid species from the streams of northern Indiana.

The detailed records of most of the Odonata collected in Indiana since 1899 have been preserved in the note books of Williamson and of the author. Except for the first eight years of this period and three later years for which the number of specimens of each species have not been preserved, these records include for each collection, the species taken, the number of specimens of each, exact locality, date and, frequently, notes on time of day, weather conditions, the observed habits and the

abundance of certain species, or other facts of interest. These records are from all sections of the state. Only 11 counties are without records for at least one species and only six others have records for less than five species. The number of species recorded from each county and the collecting stations where specimens have been taken are shown on the accompanying map (Fig. 1). The records are likewise spread over the

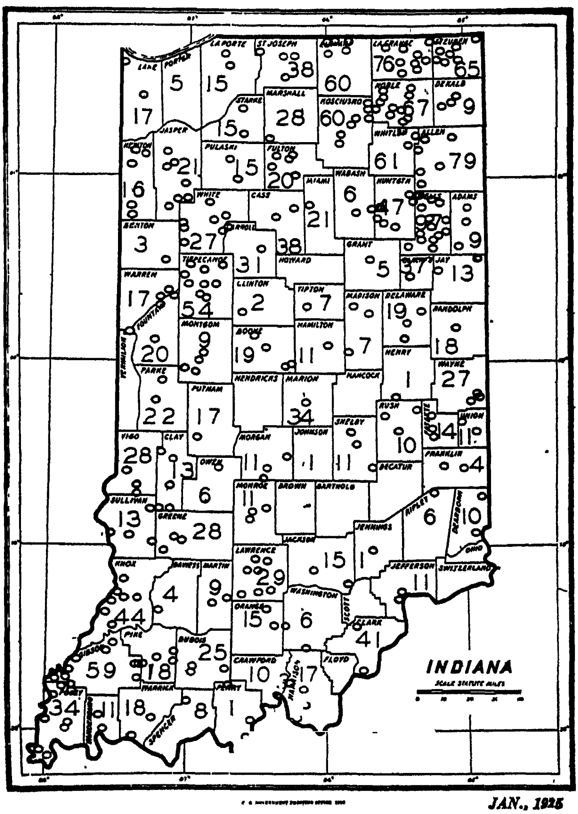

Fig. 1. Map of Indiana, showing the number of species of Odonata recorded from each county and the collecting stations (indicated by ovals) from which specimens are recorded.

years. No year since 1900 is without records although the collections for certain years were not recorded separately. During this period of 41 years an average of about 52 species has been recorded for each year (or two-year period in five cases in which the collections for two years were tabulated together). A total of over 21,000 specimens, or an average of 808 per year (or two year period) are recorded for the 26 periods for which the number of specimens are listed. The "poorest" year was 1918, when only 25 specimens of 12 species were taken; in only three

other years, 1901, 1909, and 1937 (32, 31, and 29 species respectively) were less than 35 species collected. The best years were 1932-1933 (over 2500 specimens of 90 species), 1927-1928 (3040 of 74 species), 1916 (an unrecorded number of specimens of 71 species), and 1934 (2105 specimens of 62 species).

These records appear to be sufficiently extensive and representative to provide a measure of the relative abundance of the different species in the state. The latest papers on Indiana Odonata have been a series of articles (Montgomery 1942, 1944, 1945) summarizing the records to give such a measure. The records were tabulated by thirds of months, and time-frequency graphs were constructed to show the relative abundance of each species during the season of flight (or period of adult life).

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Early Contacts of European Science with the Indian Corn Plant

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Among the problems laid on the doorstep of European science by the discovery of America none have had greater interest to the botanist than those connected with the well-known Indian corn plant. Its appearance on the scene caused at the time only a faint ripple of interest in the stream of western history; but it was ultimately to exert probably a greater economic influence than all the gold that the Spanish explorers hoped to find, and it has had no less botanical and historical significance. It has been particularly interesting to trace in detail the steps by which this plant first became known to Europe.

The story begins early in November, 1492. The little fleet of Christopher Columbus was anchored somewhere along the north coast of Cuba while small parties explored the country, trading with the natives, noting the peculiarities of the people and their surroundings, and accumulating samples of the resources of the region to be taken back to Spain. On Friday, the second day of the month, the Admiral had sent inland an exploring party of two Spaniards and two Indians, with instructions to return in six days. The two Spaniards were Rodrigo de Jerez and Luis de Torres, the latter a versatile linguist.

For some reason they did not remain six days, but, after going twelve leagues inland, returned to the ships on Monday night, November 5, and reported on what they had found. Among other things, they had seen a great quantity of a new kind of grain which the Indians called *mahiz*—but which the Spanish insisted on calling *panizo*, their name for millet—and from which a palatable kind of bread was made.

There is no further description of the plant, but, if the full import of this discovery had been realized, it would have been worth much more than the two or three lines devoted to it in the Journal of the voyage. This seems to be the first record of the Indian corn plant in the annals of Old World civilization.

As we read the old records, however, we find another statement which causes us to wonder if Columbus did not actually see the plant a few days earlier than this. On October 16, as he looked over the level, green fields of Haiti, he noted that this would doubtless be a good place for growing panic grass throughout the year. A later commentator[1] thinks that Columbus had already seen maize at this time and was speaking of it, but he may simply have meant that here would be a good place for growing the millet which he had known in Europe. This transfer of names of plants, by explorers who knew little botany, and at a time when

[1] Las Casas (1875, ch. 42) says: "———— y bien atinaba a la verdad, porque todo el año ———— o al menos dos veces, se sembrada y cogia el grano del maíz que aqui el Almirante llamaba panizo."

nomenclature was not well stabilized, is to cause endless confusion all the way along, and the bare name of a plant will by no means identify it. In view of the ambiguity of the record of October 16 we conclude for the present that the note of November 5 is the first mention of the plant in western history.

There had been earlier European visitors in America, and some authorities have entertained the idea that the corn plant was seen by at least one exploring party long before 1492. The old records of the Scandinavian explorations made nearly a thousand years ago mention "self-sown cornfields" and "new-sown" corn and state that, on one occasion, an "ear of corn" was found. Those familiar with the Icelandic language tell us, however, that the word translated "ear of corn" might as well mean "head of wheat," and there is a strong presumption that the plant which the Northmen saw was some wild grass more like the common cereals of Europe. Even if they reached a point as far south as Cape Cod, it is doubtful that the corn plant had migrated that far northeastward by that time. Moreover, the word "self-sown," if it means anything at all, practically eliminates corn, for it has never been found growing in the uncultivated state, and the bleak shores touched by these explorations would be one of the last places in the world where anyone would expect to find it growing wild.[2]

Then, there is another story to which we must pay our respects although it has less direct bearing on our immediate problem. A persistent idea breaks out from time to time that maize was known in China previous to the discovery of America by Columbus. Some have thought that it originated in Asia and made its way to America in ancient times; others grant that it is a native of America but was taken to Asia long before 1492.

In 1909 there was found in western China a kind of corn which seemed to differ from American varieties in many ways (Collins, 1909), especially in the physical texture of the endosperm; and these differences were cited as evidence of a long isolation of this variety. Curiously enough, this kind of endosperm has been found in at least four other grains of southeastern Asia, and, with few exceptions, it is absent from the same cereals in other parts of the world. Whether this is a rare coincidence or the result of some elusive single hidden cause is not known at present.

Several Chinese scholars state that there are in the old literature indisputable evidences that corn grew in China in ancient times; but these authorities are not botanists competent to identify the plant infallibly, and the references are vague and, in the modern sense, unsatisfactorily documented. Even though, as is often stated, the meaning of a Chinese character never changes, its application to a plant is no more exact than the author's understanding of the plant. There is also a strong suspicion that, in some cases at least, these reports are strongly colored by a national pride.

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[2] For an evaluation of the controversy on this point see: Andrews (1913), Fiske (1891), Fernald (1910), Harshberger (1893).

The record most often cited is a picture and a short description published in an old Chinese work on natural history. The date is uncertain, possibly as late as 1597, long after Magellan's voyage.

The consensus of dependable authority today is that all these considerations are greatly outweighed by the definite evidences that maize is of American origin and that the agricultures of the two hemispheres were entirely separate in pre-Columbian times. (Laufer, 1907; Merrill 1930, 1933.) But we relish a spectacular story, and many a traveler, in no way qualified to pass judgment on such questions, has returned from China to tell us, on no better authority than some positive but wholly unsubstantiated statement, that we are all wrong about the idea that maize originated in America.

If we feel that Columbus should have said more than he did about maize on that November day in 1492, we should recall the nature of the man and his mission. He was not looking so much for new things as for a new route to things already known, and he spent a great deal of time on the first voyage attempting to identify the islands of the Caribbean region as outlying parts of the East Indies. Moreover, he and his followers were not the kind of men who would be expected to make correct evaluations of agricultural resources or to become enthusiastic about botanical curiosities; and probably no explorer in all time was ever perplexed by a greater wealth of new botanical material.

Then, there is the additional fact that we do not know exactly what Columbus did say about maize. He kept a journal with meticulous care and took it back to Spain; but the original, which would certainly be one of the most precious documents of all history, has been lost; and, as far as we know, there is no exact copy of it in existence. Severeal contemporary historians had access to the Journal and used it freely in their writing, sometimes quoting sections, but usually paraphrasing and adding other material from letters and conversation of sailors who accompanied Columbus. The writings of three men are outstanding. Columbus' son, Ferdinand, used the Journal in writing a biography of his father. Bartolomé de las Casas, who was with Columbus on the third voyage and later spent many years in Mexico, quoted the Journal freely in his extensive writings. And Peter Martyr, later to be official counselor in the court of the Emperor Charles V, combined parts of the Journal with a great deal of information gleamed from other sources when he wrote his famous Latin treatises known as the *Decades*.

Some of these accounts were begun very soon after the news of the great discovery trickled back to a select few connected with the Spanish court. Peter Martyr, for example, wrote the first book of the first Decade in the latter part of 1493 and the second book early in 1494 (Williams 1930, p. 817). But publication was delayed for several years. This was partly because of physical limitations, the art of printing being not yet a century old, and partly because Spain wished to withhold the great news until she had strengthened her position to exploit the newly discovered lands. Even when the first book of Martyr's first Decade was officially published in 1511, the crown was a little uncertain about the wisdom of the release, and, after a few copies had been printed, certain

changes were made, particularly the omission of a map. (Thacher 1903, 1:35-36).

This first book was revised and published again, at Seville, in 1516, and in it, in the midst of a miscellany of information about the plants, animals, minerals, physiographic features, and people of the West Indies, we find a significant statement, which has been translated as follows:[3]

"They make also another kynde of breade of a certayne pulse, called Panicum, muche lyke unto wheate ——— but ——— longer by a spanne, somewhat sharpe towarde the ende, and as bygge as a mannes arme in the brawne: The graynes whereof are sette in a maruelous order, and are in fourme somewhat lyke a pease. While they be soure and vnripe, they are white: but when they are ripe they be very blacke. When they are broken, they be whyter then snowe. This kynde of grayne they call *Maizium*."

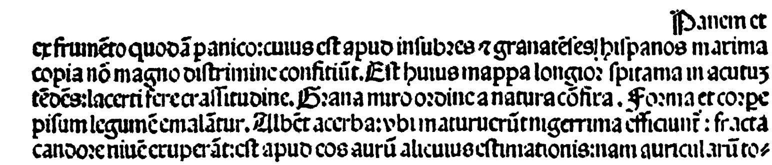
Panem et
ex frumēto quodā panico: cuius est apud insubres & granatēses hispanos maxima
copia nō magno discrimine cōficiūt. Est huius mappa longior spitama in acutū
tēdēs: lacerti fere crassitudine. Grana miro ordine a natura cōficta. Forma et corpe
pisum legumē emulātur. Albēt acerba: vbi maturuerūt nigerrima efficiunt: fracta
candore niuē exuperāt: est apud eos aurū alicuius estimationis: nam auricularū to-

Fig. 1. Description of maize in the first book of Peter Martyr's first Decade, edition of 1511. From a copy of the book in the John Carter Brown Library, Providence, R. I. Although the name of the plant is not given, the text is otherwise almost exactly the same as in the edition of 1516, which does give its name.

This is the first printed account of the plant in which the identifiable name *maize* is applied to it. In modern botanical literature it has sometimes been regarded as the first published account. The edition of 1511, however, gives essentially the same account, except that it omits the last sentence (Fig. 1).

An earlier edition of the book, published in 1504 in the Venetian dialect, and apparently without the author's permission, has been searched for reference to maize, but without success, unless the following passage is thought to be significant: "certain red grains of different colors, more sharp than the peppers we have.[4]

Perusing the record a little farther back, we come to another account whose significance seems to have been overlooked alike by botanists and historians. It must bring us near the end of our search for the first published record, for it appeared probably not more than two years after the discovery. When a part of the ships of Columbus' second voyage started back to Spain on February 12, 1494, one of them carried a letter, written by one Guglielmo Coma, describing the newly discovered lands. This letter, combined with some material from other sources, was published as a single document by Nicolo Syllacio late in 1494 or early in

[3] Richard Eden's translation (Arber, 1885, p. 67).

[4] Thacher's translation (1903, 2:488) of the following (p. 459): "certi grani rossi de diversi colori pin acuti del peuare che noi habiano."

1495.[5] Through this unauthorized little "scoop" its few readers received the first public news of the great discovery. In speaking of the food of the Indians, Coma (or Syllacio) says:[6]

"There is here, besides, a prolific sort of grain of the size of a lupin, round like a vetch, from which when broken a very fine flour is made. It is ground like wheat. A bread of exquisite taste is made from it. Many who are stinted in food chew the grains in their natural state."

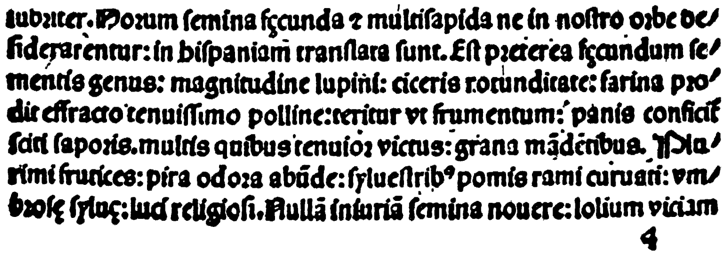
subiter. Porum semina fęcunda & multisapida ne in nostro orbe de/
sideraréntur: in hispaniam translata sunt. Est preterea fęcundum se/
mentis genus: magnitudine lupini: ciceris rotunditate: farina pro/
dit effracto tenuissimo polline: teritur vt frumentum: panis conficit
sciti saporis. multis quibus tenuior victus: grana mandentibus. Ma/
rimi frutices: pira odora abūde: syluestrib⁹ pomis rami curuati: vm/
brosę sylue: luci religiosi. Nullā iniuriā semina nouere: lolium viciam

Fig. 2. Description of a plant which is almost certainly maize. From the Coma-Syllacio letter of December, 1494. Apparently the first printed reference to the plant. Copied from Thacher.

What could this have been but Indian corn? Moreover, this passage and the text immediately preceding and following it read so much like Peter Martyr that it is evident that they had a common origin. This suggests one of two interesting possibilities: the Coma-Syllacio letter represents a still earlier theft of Martyr's thunder, or Martyr's account of maize was based upon observations made on the *second* voyage rather than on the first as has ordinarily been supposed. From differences readily discernible between the editions of 1511 and 1516 and the spurious edition of 1504 it is evident that, although Martyr may have written the first draft of the first book in 1493, he made changes in the manuscript from time to time, and it is conceivable that he incorporated in the two officially published editions material taken from the Coma letter. Whatever the truth of this may be, the fact remains that we have in the Coma letter a published account of the maize plant which antedates by some seventeen years the one usually cited as the first.

Following the introduction of corn into Europe by the Spanish and other explorers at the end of the fifteenth century, it quickly spread through the countries where it could be grown profitably. It was soon recognized everywhere as a botanical curiosity, and its agricultural possibilities began to be investigated and put to use.

Western Europe was an interesting place at this time. The spirit of scientific investigation was just coming out of a sleep of more than a thousand years. A few investigators still searched the pages of Theophrastus, Aristotle, Dioscorides, and the Plinys for answers to their questions about such New World plants as maize, tobacco, and the potato,

[5] According to Thacher (1903, 2:218). Williams (1930, p. 817) gives December 13, 1494, as the definite date of publication.

[6] Thacher's translation. For the original Latin, see Figure 2.

but they found nothing satisfactory. They had at last to admit that here were things which had been previously unknown. To get anywhere, they had to use their own eyes and to believe what they saw. This new philosophy was most stimulating.

For the reactions of this embryonic modern science to the corn plant, we turn next to the outstanding botanical publications of the sixteenth and seventeenth centuries, the *Herbals* of Fuchs, Ruellius, Bock, Dodoneus, Matthioli, Tabernaemontanus, Parkinson, Gerard, and many others. These treatises were, in a way, the precursors of our modern local, state, and regional floras; but they were less technical, usually included much fuller discussions of the history, properties, and uses of plants, and frequently wandered off into almost meaningless philosophical rambles.

The first mention of maize in the strictly *botanical* literature was in a little-known herbal by Jerome Bock, in 1532, and it was again mentioned by Ruellius in 1536; but it was the publication of the first picture of the plant, and a better description, in the first edition of Fuchs' herbal, in 1542, which brought it clearly to the attention of the scientific public and gave it a permanent place in the literature of science.

It would be an interesting thing to trace the history of the plant through the various editions of numerous herbals for a period of two hundred years or more, but this would take us quite beyond the limits of our present undertaking and would call for the examination of many highly prized volumes in widely scattered libraries.[7] A few examples will have to suffice.

The uniformity of many of the accounts of maize and the repetition many times over of obvious errors indicate that it was common practice for authors to copy or adapt earlier descriptions and that few of them had any first-hand knowledge of the plant. It seems likely that some who included it in their herbals had never even seen it, and the published illustrations justify the inference that the artists were sometimes no better off.

The early authors recognize maize as a member of the cereal family and describe it as a kind of wheat or millet. They usually give reasonably good descriptions of the roots, stem, leaves, and tassel and then hasten to add that, although the tassel is similar to the inflorescence of some of the other cereals, it does not produce grain. The ear is recognized as a unique structure, having no homologue in the other cereals, and it and the surrounding husks are usually described in fairly accurate detail.

Maize stands all alone among the cereals in the variety of color of its grains, and, as would be expected, this is noted by all the early writers. They observe that the silks and staminate flowers also vary in color, and some state that these organs are of the same colors as the grains on the same plant. This entirely erroneous idea was so plausible that

[7] For the opportunity of examining a large number of the Herbals, I am greatly indebted to the libraries of the University of Notre Dame, the American Philosophical Society, the Philadelphia College of Physicians and Surgeons, and the University of Pennsylvania.

apparently no one though of challenging it although evidence to the contrary was there before their eyes all the time; and we find it in the works of various herbalists for more than a century.

Several of the herbals give an account of an Indian method of planting corn which is apparently not extant in the ordinary run of American travel literature of that time. The following is a translation of the story as it occurs in the works of Matthioli, Durante, Dalechamps, and Tabernaemontanus, between 1540 and 1630:

"The Indians plant this seed, which they call *Malitz*, in the following manner: Many of them go into the field at the same time and arrange themselves in a straight line; and then, with a pointed stick in the right hand, they make a hole in the ground and straightway, with the left hand, place in each hole five or six grains, closing the hole with the foot so that the seed will not be eaten by the parrots. And so, measuring off distances one step at a time, they fill the entire field with seed as they move across it."

The origin of this story was a puzzle for a time, but it seems to have been told first by Oviedo in his account of the West Indies, parts of which were available to European scholars early in the sixteenth century.[8]

In the literature of these early days there is much disagreement as to the economic value of maize. Some regard it as the equal of wheat for food and say that good bread is made from the meal; others say that it is inferior to the other cereals and to be recommended only in case of extreme necessity or for those doing the hardest kind of work. The use of corn meal for making mush or porridge was known, but in the herbals examined there is no mention of green corn as a food, although the early explorers very generally speak of its use in this way by the Indians.

Corn bread is cited as the cause of various digestive ailments, and, when it is used exclusively for any considerable time, it is said to produce "grosse blood which breedeth itches and scabbes." So the problem of vitamin deficiency in an all-corn diet is at least as old as the use of the plant in Europe. In general, the herbalists regard it as a suitable food for livestock rather than for man.

In many of the early accounts there lingers the idea that the corn plant came from western Asia and that it should be possible to reconcile its characteristics with the writings of Pliny or others of the Classical period. This is reflected in such names as Turkish corn, Triticum Bactrianum Plinii, Milico Indico Pliniano, Frumentum Turcicum, Triticum Turcicum, Frumentum Asiaticum, and Turkish wheat. Europe still had a confused picture of the New World in relation to the Indies which had long been known, and it is a fact that usage with regard to the names of things often lags far behind knowledge of the things themselves. We still call a certain bird a turkey although we have known for more than four hundred years that it is American in origin.

Many of the herbals are well illustrated with woodcuts, a quality which will be more appreciated if we recall that photographic methods

[8] Book 7, chapter 1. See Oviedo (1851, p. 263).

of platemaking were unknown and each figure had to be patiently cut by hand. The first published figure of maize, in Fuchs' quarto herbal of 1542, is one of the best. For scientific accuracy and artistic quality it was not greatly surpassed during the herbal period, and it would not seem much out of place in a modern publication (Fig. 3).

Color printing in the modern sense was, of course, impossible at this time; but it was apparently intended that the pictures in some of the herbals should be hand-colored after they were printed. In some

Fig. 3. Illustration from Fuchs' Herbal of 1542. To the best of our knowledge at present, this was the first published picture of maize.

copies of Fuch's work, the grains of one partially exposed ear have been colored with zones of blue, yellow, and red, and the author apparently intended that they should be, for he says:

"This picture shows, in one sheath, grains of four colors, although, of course, any one ear would have all the grains of one color, yellow, purple, red, or whitish. We explain this lest the picture be misleading."

If the color had been applied to individual grains, with less regularity of arrangement, the author's apology would not have been neces-

sary, for, contrary to his opinion, and, at that time, to all reason, it is possible for all these colors to appear naturally in a single ear.

When the Spanish found the corn plant in the West Indies and took it to Europe, they called it *mays* or *maizium*, these being the Spanish equivalents of the name applied to it by the Indians.[9] But the Spanish were not in a position of scientific leadership, and the plant was introduced to European science chiefly by way of the herbals and the gardens of Germany, England, France, and Italy; and, in the absence of the direct influence of the native name, its derivaties received less favor than they deserved.

The herbals use various forms of the word *maize*, but they give preference to names based on the Latin *Frumentum* or *Triticum* or the Anglo-Germanic *Korn*. The English word *corn* has long been used in a generic sense for all kinds of cereals, or specifically for the commonest grain crop in any one locality, and in this case the use of the existing term was expanded, and maize was called *Indian* corn. It is to be regretted that the name *maize* was not universally adopted in English-speaking countries, as it has been in parts of continental Europe and in Latin America. It is simple enough for easy adaptation and so specific that its meaning is usually clear.[10] But these are not the criteria which determine what names are to be given to things, and we shall continue to call the plant *corn, Indian corn,* or *maize,* as dictated by the sensibilities of our readers or hearers or by the desire for variety.

As we come to the end of the herbal period, some 250 years after the discovery of America, the people of Europe still knew very little about the plant of which we speak. They had accepted it when it was brought to them and were finding uses for it in places where it could be grown, but it had not greatly stimulated their imaginations, and there was still much prejudice against its use as a food. They had grown it as a curiosity in their gardens and had pictured it, described it, and given it a name; but botanically it was still almost as much of a puzzle as ever. European science never did, up to this time, quite get the idea that here was a new and extremely interesting plant, worthy of independent consideration, and not merely something to be leaned against the accumulated mass of information about wheat and oats and rye. The colonist and the explorer, amazed at the broad fields of the plant in America and fully aware of the part that it had played in the development of great civilizations, were far ahead of their European scientific brothers in grasping its significance.

American science, in the meantime, was taking the plant at its face value. Practical men, such as Thomas Hariot, Captain John Smith, and the Mayflower company, recognized its value, adopted and improved the Indian methods of cultivation, and were investigating and extending its uses. And Colonial scholars, such as Cotton Mather, James Logan, and Paul Dudley, were sifting Indian lore for botanical and historical

[9] The questions raised by Wiener (1920, 1:118-125) about the origin of certain words used by Columbus seems to have been pretty well answered by Williams (1930). For a discussion of the world *maize*, see pp. 830-832.

[10] The name has, unfortunately, been applied to some of the sorghums.

information and making experiments on the flowering, pollination, and hybridization of maize and reporting their results to an indifferent Royal Society in London. In these ways an important groundwork was being laid for the prominent role which maize was to play in the modern era of agriculture and botany which was just then beginning.

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Men of Science in Indiana Past and Present

JOHN S. WRIGHT, Indianapolis

The history of Science in Indiana may be said to have begun about 150 years ago with the advent of General George Rogers Clark, who came to this territory first in 1778 and who was a resident of the present area of the state much of the time thereafter until his death in 1818.

Clark was a neighbor and a boyhod friend of Thomas Jefferson from whom he probably acquired his interest in science. Throughout his life as opportunity offered he was in communication with Jefferson and on one occasion sent him specimens of mammoth bones from the Ohio Valley.

Clark's powerful, active mind and training as a frontiersman and soldier made him an acute observer, constantly studying the Indians and the features of the country over which he fought. The Indian mounds engaged his attention. He discussed them with intelligent Indians and left among his records a paper on their origin, sharply at variance with the opinions then held by archeologists. Clark's conclusions have since proven to be substantially in accord with the deductions of those who later made studies of the excavations.

In his biography of Clark ("Clark of the Ohio"), Frederick Palmer says, Audubon, who came to Louisville in 1807, visited Clark, who on acquaintance said Audubon was a man after his own heart; that he was not like some of the "American Museum fellows," speculating on second-hand information (a reference to their theories of the origin of the mounds), but going out and seeing the life of the forests for himself. Audubon's notes of his visits with Clark were lost. Clark made none.

In 1803 before starting on the celebrated Lewis and Clark expedition, William Clark called on his famous brother, the General, at Clarksville, Indiana, from whom it is believed that he received priceless advice on the conduct of the expedition. General Clark was keenly interested in the Indians and in the scientific results of the exploration, and must have been delighted with the account William brought him when he made his last visit on the return of the expedition in 1806.

Although Clark published nothing on scientific subjects there was at least one paper on archeology in his records, referred to above. General Clark manifested repeatedly the proper spirit of the investigator, appreciation of scientific work and of true scientists. It is probably quite within bounds to claim him as the first man of science or of known scientific interests in Indiana.

The New Harmony period of science in Indiana runs from about 1825 to approximately 1860. During this time some of the most distinguished of American and a few celebrated European scientists visited New Harmony. Certain eminent scientists were resident in the community and did important work there. For example, David Dale

Owen made New Harmony his home and the seat from which he directed government geological surveys of sections of Iowa, Illinois, Minnesota, Nebraska, and Wisconsin during much of the period between 1837 and 1852. Considerable has been written of the New Harmony group so that it should not be difficult to assemble the facts essential to the history of this period of science in the state.

Probably the details of the story of science in the state for the first ten or twenty years following the beginning of the Civil War will require considerable searching of the records in the archives of the various colleges and universities of Indiana.

Once it becomes known that a responsible group in the Academy is endeavoring to prepare a history of science in the state it may be found that individuals interested in special fields of science have collected data on men and work in their respective fields and that they will be willing to contribute from their collections.

In 1885 Indiana was the home of a group of brilliant and purposeful scientists, some of whom were leaders of national standing in their respective fields; among them were Jordan, the Coulters, Mendenhall, Noyes, Campbell, Butler, and Branner. When these men organized the Academy their sponsorship gave it immediate standing and the Indiana Academy of Science has been one of the most successful of all similar state institutions. Until a high degree of specialization was reached, resulting in the organization of state branches of certain groups, for example the Indiana branch of the American Chemical Society, the Academy of Science membership included nearly all residents of the state engaged in scientific work. Its publications are a fairly complete index to the scientific interests and accomplishments in Indiana for a period of approximately 25 years.

Records of the special scientific societies supplementing the Academy's own proceedings will contain the majority of the material needed to write the story of the various fields of research in the state since 1885.

A comprehensive account of science in Indiana will include some of the activities of the state Audubon society, the engineering societies, research departments of technical industries, the public health service, the state departments having to do with conservation and the medical group.

In contemplating the undertaking, which happily has begun under a committee headed by Dr. Edington, it appears that the final committee should include a representative of each department of science, and one who has been in the state long enough to know something of the traditions of our higher educational institutions and of the Academy of Science.

The committeeman on geology, for example, could enlist the aid of someone in each college to search the records and report on all men connected with that institution, both past and present, who as geologists deserve a place in the record. Committeemen representing astronomy, botany, chemistry, engineering, mathematics, medicine, physics, zoology, etc., etc., could do the same with respect to their departments.

The Biographical Section

The most useful and prized section of a volume on *Men of Science in Indiana Past and Present* will be the biographical dictionary or Who's Who. The story of science in the state as suggested above although quite important, would be to an extent prefatory, as the interest probably will center on the biographies.

The relationship of the man to the State in respect to his scientific career should be so clear that the authors and the sponsors of the biographies will not be open to the charge of claiming too much for Indiana science. An examination of a few biographies makes it apparent that there are seven or more degrees of connection between Indiana and men of science. These range from that of the native sons educated and residing in the state throughout their careers to that of men born and educated elsewhere but resident in the state for a short time only; men whose major work was done elsewhere. The following are examples of degrees of relationship:

Men of Science in Indiana Past and Present

1. *Native*—Education and career in the state.
   Examples—Amos W. Butler, Charles C. Deam, A. L. Foley.
2. *Native*—Educated in Indiana, career chiefly elsewhere.
   Examples—Harvey W. Wiley, Henry L. Bolley, the Cory brothers, H. T. and C. L., W. C. Allee.
3. *Native*—Higher education and career elsewhere.
   Examples—John S. Billings, M.D., George Brown Goode, George A. Reisner, Clarence A. Mills, M.D.

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4. *Not Native*—Educated and worked in Indiana.
   Examples—John M. and Stanley Coulter, Julius A. Nieuwland, Willis S. Blatchley.
5. *Not Native*—Educated in Indiana but worked elsewhere.
   Examples—None occur to me now but doubtless the the alumni rolls of many Indiana colleges contain the names of such.
6. *Not Native*—Educated elsewhere but worked in Indiana.
   Examples—Gen. George Rogers Clark, David S. Jordan, T. C. Mendenhall, Thomas Gray, J. C. Arthur, and hosts of others.
7. *Not Native*—Educated and worked in science elsewhere but had brief residence in the State, or made visits in pursuit of scientific work.
   Examples—Constantine S. Raffinesque, John J. Audubon, others temporarily associated with the New Harmony group, Heinrich Schliemann, whose residence in Indianapolis for one year to obtain a divorce was of doubtful credit to the State.

With a list of names for consideration, questionnaires could be prepared and submitted for the information needed to prepare terse biographies. The American Men of Science style of biography is tentatively suggested as a model, to which might be added a brief bibliography of the more important papers and a statement of outstanding work of the individual, especially that done in Indiana.

Living subjects could be asked to submit their own biographies on a form provided. Obviously all such autobiographies would have to be subjected to careful editing to attain uniformity of style.

If each biography contained a terse statement of the ancestral stock of the subject, indicated the occupation of father, necessity and extent of self-support in college, valuable data would be afforded for statistical studies. It might not be expedient to publish all such data, nevetheless it would be worth collecting.

The Bulletin of the A.A.A.S. for July, 1944, carried an editorial by Secretary F. R. Moulton on the "Early Environment of Eminent Scientists." In this he said that there is a general impression that eminent scientists have had unfavorable educational environments in their early youth. This impression is neither affirmed nor denied but used by Dr. Moulton to point out the interest and importance of an investigation of the facts because of the light they would throw upon the problem of education and the factors which contribute to success in science.

The editorial states that men who have achieved high success in nearly every field have come from the farms and villages and quotes a recent advertisement as stating that every one of the presidents of the 18 operating companies of the Bell Telephone System began work as a clerk or in some other lowly position at a salary ranging from $25 to $65 a month. These successes, Dr. Moulton concludes, were not due to educational opportunities or to the lack of them and he asks "What factors internal and external are conducive to exceptional achievement?"

In the preparation of a volume on Men of Science in Indiana, it is recommended that in the assembling of biographical sketches an effort be made to include data that would throw light on early environmental and other factors that dispose men and women to scientific pursuits. With this in view the committee should include a member trained in statistical methods who could make some valuable deductions from the data.

About ten years ago I had the Fourth Edition of American Men of Science (1927) carefully examined and all biographies of men with Indiana connections marked. There were 13,500 entries in the volume; 692 were of men born or then living in Indiana, or 5.1 per cent of the whole, whereas the population of the state was then but 2.6 per cent of the national total.

Scientists living in the state in 1927	215 or 1.6 per cent
Scientists born in the state	540 or 4.0 per cent
Scientists both born and living in the state in 1927	63 or 0.46 per cent approx.
Scientists of Indiana connection starred as among the 1,000 distinguished	49 or 4.9 per cent

On the whole, men of science with Indiana connections made a creditable showing in 1927. Probably they would appear quite as well now.

In all probability Dr. Edington and his committee have considered many if not all of the details of procedure mentioned in this paper, nevertheless I felt an urge to present them as a result of contemplating the subject for several years, also to emphasize the richness of opportunity which confronts those who assume the work. It is predicted that the subject will grow in attractiveness and significance as more of the Academy members become engaged in helping the editorial committee.

The cost of collecting and editing the data will eventually amount to considerable. A small fund is now available for the preliminary work. From year to year the Academy should set aside from current net income such amounts as may be judged expedient to continue the work and to supplement other funds that may be contributed.

A carefully prepared brief history of the development of science in Indiana with a biographical dictionary of our men of science, past and present, would be a credit to the Academy, reflect honor on the State, and possibly incite similar work in other states. May the committee be confirmed, strengthened and supported in the enterprise.

MATHEMATICS

Chairman: PAUL M. PEPPER, University of Notre Dame

The MATHEMATICS SECTION met with the Indiana Section, MATHEMATICAL ASSOCIATION OF AMERICA.

Professor Juna L. Beal, Butler University, was elected chairman of the section for 1945.

Some remarks on final grades in freshmen mathematics. M. W. KELLER and H. F. S. JONAH, Purdue University.—In this paper the authors present some data which indicates from this preliminary study that there are variations in final grades when ordinary final examinations are given, when no examinations are given, and when uniform objective final examinations are given.

e and π in Elementary Calculus. KARL MENGER, University of Notre Dame.—We introduced the "natural" exponential line $y = e^x$ as that member of the family of exponential lines $y = a^x$ which has only the point (0, 1) in common with the auxiliary line $y = x + 1$; and the "natural" tangential line of period π as that member of the family of tangential lines $y = \tan \frac{2R}{p} x$ which touches the auxiliary line $y = x$. (Here R denotes the measure of a right angle, p the period of the tangential function.)

On certain recursion inequalities with applications. PAUL M. PEPPER, University of Notre Dame.—Given a switchboard with n terminals and wires with which to connect the terminals in pairs, one may ask "What is the greatest number of cross-connections which can be made without there being somewhere three terminals each two of which are joined by a wire?" Knowing the answer to this question, one may ask for "a distribution of the maximum number of wires on the terminals in such a way as to form no triangles (i.e., no 3 terminals each 2 of which are connected)." In solving these and allied problems one is led to the following auxiliary problem: "Let a, b, c and u_o be given integers with a greater than or equal to o, find a simple formula for u_n in terms of a, b, c, u_o and n if u_n is the least integer satisfying the inequality u_n greater than or equal to $((n + a + c)u_{n-1} - (n + b))/(n + a)$, $n = 1, 2, \ldots, \infty$. The present paper contains a solution of the first two problems and the solution of a 2-parameter family of the recursion inequalities with arbitary u_o.

The Great Mathematics Books in the College Curriculum

SISTER GERTRUDE MARIE, O.S.F., Marian College

Mathematics educators are acutely sensitive to the existence of a double-aspect problem involving mathematical inadequacy. The first has to do with the inefficiency of students in the basic computational skills. The failure of large numbers of servicemen to qualify mathematically has spot-lighted a weakness abundantly evident in the results of standardized achievement tests and in daily classroom experience.

The second, more fundamental aspect, is presented by the conflicting evaluations of mathematics in current studies of education. According to one group of thinkers, mathematics lacks the "liberal" element demanded for inclusion in general education; others completely justify its liberal arts affiliation.

Edward Leen, for instance, in his recent book, *What is Education?* says of British secondary schools:

> "In our national system of education an altogether undue importance is given to the study of mathematics. Its value as a training for the mind is greatly exaggerated. . . . To impose on all students the extensive programme of mathematics that appears in our syllabuses is to lay on them a burden which hampers intellectual progress" (22).

E. K. Rand in the scholarly article "Bring Back the Liberal Arts" published in the *Atlantic Monthly*, June, 1943, unhesitatingly lists mathematics as one of the arts to be recovered. Wriston establishes its liberal arts claim on the ground of the basic disciplines of precision and reflective synthesis (41).

Sister Helen Sullivan, O.S.B., writing in the *Catholic Educational Review*, April, 1944, bases the affirmative answer to the first half of her title question, "Is Mathematics a Liberal Art or a Lost Art?" on the intrinsic values of mathematics as "a mode of thought, a system of philosophy, a means for answering some of the ultimate questions of reality," as well as on its traditional association with the fine arts as furnishing the basis of symmetry, proportion, balance, and perspective in art and architecture, and of harmony in music (39).

Oystein Ore, of Yale, points out that the correct attitude toward the problem of scientific vs. humanistic education, is a serious attempt to bring the two in contact. "Mathematics in the last century," he writes, "has experienced a brilliant growth in conjunction with the natural sciences. It should not be forgotten, however, that mathematics by its traditions and long history belongs to the liberal arts; it is evidently not to be regarded mainly as a technical tool of the sciences" (28).

Reevaluating the aims, the scope, and the content of college mathematics in accordance with an integrated objective of education, and directing learning-teaching procedures toward the attainment of that

objective, will do much to clarify the true nature of mathematics and to insure it an abiding place even in a rigorously defined liberal arts program.

Such a reevaluation was made at St. John's College, Annapolis, seven years ago. Leo Leonard Camp, instructor at St. Mary's College, California, who spent a year and a half in observation of the Restored Liberal Arts program in operation there, is convinced that students from St. John's know more and that they have better disciplined minds; they combine rigor with breadth (9). From the central idea of that program—the great books—this paper takes its orientation. The title, "The Great Mathematics Books in the College Curriculum," calls for explication. It evokes the questions:

1. What constitutes a great book?
2. Which are the great mathematics books?
3. What is their position at present in college curricula?
4. What advantages does their introduction into the curriculum offer—for students, for teachers?
5. How can they be introduced?

Books are great either in themselves or on account of their influence on other books and on the reader and the teacher (33). Six criteria, used by President Barr and Dean Buchanan of St. John's, and by President Hutchins and Mortimer Adler of Chicago, are enumerated by Adler in *How to Read a Book* (1). Except for order of arrangement, they agree with those given in St. John's catalog 1943-'44 (34). Summarized they are: 1) a great book must be a masterpiece in the liberal arts, it must direct those arts of thought and imagination to their proper ends, the understanding and exposition of truth, as the author sees it; 2) it must be immediately intelligible; 3) it must admit many possible interpretations, not ambiguities, but distinct, complete, and independent meanings, each allowing the others to stand by its side, and each supporting and complementing the others; 4) it must raise the persistent and humanly unanswerable questions about great themes in human experience—ultimate questions concerning number and measurement, form and matter, substance, tragedy, and God; 5) it is an enduring best seller; 6) it is always contemporary, intensifying the significance of other books on the same subject.

More succinctly, great books are "simply those that can most effectively induce thinking" (25). In the words of John Erskine, father of the great books idea at Columbia University, "it is the completeness of their outlook which makes great books great" (8).

There is no all-inclusive list of great books in mathematics, but the works treated below and marked with an asterisk in the bibliography at the end of this paper, do qualify according to the standards enumerated. Studied in chronological (rightly called "providential") order, they exhibit the sixth earmark. Each book is "introduced, supported, and criticized by all the other books in the list" (35).

Euclid's *Elements of Geometry* stands at the beginning of the organized study of mathematics in western Europe, not only in time but

in relation to all subsequent developments. De Morgan, in 1848, could deliberately say:

> "There never has been, and, till we see it, we never shall believe that there can be a system of geometry worthy of the name which has any material departures (we do not speak of corrections or extensions or developments) from the plan laid down by Euclid,"

and Heath, to whom the above quotation is due, (15) adds, in 1908, that, despite the valuable recent investigations in the first principles, De Morgan would have no reason to revise that opinion.

Archimedes regularly prefaces his own works with an outline of the relevant accomplishments of his predecessors. In the letter to Dositheus which introduces the *Quadrature of the Parabola*, for instance, after stating that he has used a certain lemma to demonstrate the fact "that every segment, bounded by a straight line and a section of a right-angled cone, is four-thirds of the triangle which has the same base and equal height with the segment," he says,

> "The earlier geometers have also used this lemma; for (by it) they have shown that circles are to one another in the duplicate ratio of their diameters, and that spheres are to one another in the triplicate ratio of their diameters" (4).

The lemma referred to, states that the excess by which the greater of (two) unequal areas exceeds the less, can, by being added to itself, be made to exceed any finite area. This lemma is substantially the same as that derived by Euclid from Definition 4, Book V, and used by him to prove X, 1 and XII, 2 (3).

Apollonius, in his preface to the first of his eight books of *Conics*, speaks of Euclid's not having completely worked out the synthesis of the "three- and four-line locus," a thing impossible without some theorems proved by himself (2). It is in this same book that he makes his chief original contribution to the development of geometry, by relating the conic sections to their diameters and tangents as to the axes of a coordinate system.

Oresme's mid-fourteenth century invention of another form of coordinate system is the subject of his treatise *On the Breadths of Forms* (29).

The writings of Viete, Cavalieri, Roberval, and especially Fermat figured signally in the perfecting of analytic geometry, but Descartes' *La Geometrie* has been ranked traditionally as the cornerstone of that science. Descartes seems to be the first to have referred several curves of different orders simultaneously to the same set of coordinate axes. He distinctly does this at the beginning of his demonstration of the famous problem of Pappus. (Having given three or more lines in position, required to find a point from which an equal number of lines may be drawn, each making a given angle with one of the given lines, such that the rectangle or parallelepiped on certain of them shall equal, or, at least, bear a given ratio to the rectangle or parallelepiped on the rest) (13).

That Descartes was aware of the historic association of his work is shown by repeated references to the curves which the ancients excluded from geometry. Introducing his own solutions of the problem of Pappus, he says expressly, "neither Euclid, nor Apollonius, nor any one else has been able to solve it completely" (14).

Newton's *Principia* (26), though containing the first specimens of infinitesimal calculus, owes its fame to geometrical analysis of natural phenomena. Its astronomical portions have affinity with Aristarchus's treatise *On the Sizes and Distances of the Sun and Moon* (5), known as the "Little Astronomy," and with Ptolemy's *Almagest* (31), the "Great Astronomy" (18).

Leibniz's masterpiece, expounding the calculus (*Ueber die Analysis des Unendlichen*) does not seem to have an English translation. *The Early Manuscripts* volume (23), however, has all the rigor and classic touches of the larger work.

Lobachevski's *Theory of Parallels*, a non-Euclidean classic, is by the author's own analysis, an attempt to clarify "the obscurity in the fundamental concepts of the geometric magnitudes . . . and to fill a 'momentous gap', to fill which all efforts of mathematicians have so far been in vain." For him, writing in 1840, these "imperfections" explain why geometry, "apart from transition into analytics, can as yet make no advance from that state in which it has come to us from Euclid" (24).

Riemann's *Hypotheses of Geometry* (32), demonstrating unbounded yet finite space, and Hilbert's *Foundations of Geometry* (19) represent distinctly modern advances. Cantor and Dedekind's theory of continuity, presented in *Transfinite Numbers* (10) and *Essay on Numbers* (12), round out the theory of analytic geometry and remedy a deficiency in Euclid by establishing a one-to-one correspondence between points on a line and the real number system (11).

Nicomachus's *Introduction to Arithmetic* (27), more entertaining than scientific, is Euclid's number theory in a diluted form. Peacock's *Treatise on Algebra* (30) takes the arithmetic and algebraic foundations for its two volumes, *On Arithmetical Algebra* and *On Symbolical Algebra*, from the traditional sources. Boole's *Laws of Thought* (7) applies algebra to the laws of logic. These books, then, do have a common bond.

It would be interesting to quote from each of them to establish its liberal arts challenge to thought and imagination, its literary style, simple, yet beautiful, its concern with ultimate truths. But, to quote Descartes, "I shall not stop to explain this in more detail, because I should deprive you of the pleasure of discovering it yourself," if you have not already done so.

Now, for the problem of introducing the great books into the mathematics curriculum. Is it desirable?

Wriston's comment is apropos.

> "If one seeks to stimulate ideas and to develop intellectual resourcefulness, poor books will never achieve those aims. Great minds have produced great books . . . better, by far, a struggle with Plato than easy reading about Plato and his ideas. Good as the faculty are, there are yet greater minds with which the students should make first-hand contact through books" (40).

The best current textbooks are poor when weighed in the balance of the great books. Their entire outlook is at times distorted by a professional educator's desire to publicize some particular nostrum that he has found useful. Organization of material is often the only contribution made by the textbook writer (36). What David Eugene Smith (37) says of the seventeenth century textbooks in elementary mathematics is rather generally true.

> "Their mission thenceforth was to improve the method of presenting theories already developed and to adapt the application of these theories to the needs of the world. From that time on, they ceased to be a great factor in the presentation of mathematical discoveries."

American textbooks, moreover, following the English rather than the continental type (38), tend to give a maximum amount of space to problems and a minimum to the presentation of ideas. Their dominance of college teaching results in poor assimilation and correlation of ideas.

If it is desirable from the student's point of view to substitute the "originals" for second- and third-hand books, it is doubly so from the teacher's. The great books in the college classroom would give to the teacher's knowledge greater depth and freshness. As cooperative learner with his students, he would share the new vistas of thought and inspiration which result from looking at modern scientific achievement with some of its problems unsolved. (cf. Newton's *Principia* p. 507).

There are, of course, very real difficulties involved in bringing the mathematics classics to the students. Since the great books are all of a piece, they do not fit snugly into departmentalized teaching. The teacher must be prepared to go outside the field of mathematics for their interpretation.

To illustrate. The very first definition of the first book of Euclid's thirteen books of *Elements*, variously translated "A point is that which has no part" (16), and "A point is that of which a part is nothing" (17), calls for the ability to search into Greek terminology for linguistic interpretations. It sends one to Plato and Aristotle for earlier conceptions of a point, and, through the later history of mathematics, to account for the current interpretation of that entity. It is precisely in this interlocking of the areas of learning that the liberalizing influence of the great books is felt.

But what of manipulative skill? That is the other half of the theory of using the great books in the classroom, the problem of how to use them. Reading, by the students alone and by the professors and students conjointly, is one phase. In this phase the technique of reading may need cultivation. Adler's *How to Read a Book* and Richard's *How to Read a Page* are helpful directives. Then follow discussion and weighing interpretations, application and reasoned drill in application, and, finally, correlation with the physical sciences.

At St. John's College, where the great books are the core of the entire curriculum, the system comprises, for mathematics: tutorials, seminars, occasional formal lectures, and organized laboratory periods. It is in the latter that students work out the theories expounded in the great books. There is a four-year outline of such experiments for all students.

Special exercises are planned for individuals who need additional drill or insight. Experiments in physics often serve best the purpose of mathematical applications. According to Tutor Bingley, the function of the laboratory exercises is to supplement and explicate the tutorials. The drawing board exercise assigned to clarify the only two irregularities of the moon in Ptolemy, V is typical (6).

In the fourth year, specially prepared manuals and texts in the differential and integral calculus are studied along with the works of Cantor and Lobachevski.

St. Mary's College, California, which has been experimenting with phases of the St. John's program for about five years, studies the first six books of Euclid and assigns nine geometry experiments—chiefly constructions and making models or studying models already made.

How much of the great books theory can colleges adopt under their present organization? Instructors can begin or continue to enrich their own background by setting themselves to the task of reading the books. Surely they can, on occasion, bring into class a master's solution of a problem in hand. Perhaps they can keep a reserve shelf of classics, and, by definite assignments, improve the students' acquaintance with the master minds.

Systematic study in seminars or in colloquia, of the type used at Columbia, is still more effective. Honors courses in the third and fourth years, like those at Chicago, may be feasible. At least in the case of mathematics majors, departments of mathematics can prescribe a sequence of cooperative faculty-student readings, preparatory to the senior comprehensive examination.

The great books approach to college mathematics is justified, not only by the aims of mathematics, but by the objectives of general education.

In mathematics, according to the International Commission on the Teaching of Mathematics (20),

> "two ends are constantly kept in view: first, stimulation of the inventive faculty, exercise of judgment, development of logical reasoning, and the habit of concise statement; second, the association of the branches of pure mathematics with each other and with applied science, that pupils may see clearly the true relations of principles with things."

And genuine education implies the cultivation of these same habits of thought as elements of the individual's power to deal successfully with life, in its speculative as well as in its practical aspects (21).

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PHYSICS

Chairman: MASON E. HUFFORD, Indiana University

Professor R. E. Martin, Hanover College, was elected chairman of the section for 1945.

Gas mixtures for rapid explosions. R. B. ABBOTT, Purdue University.—Oxygen and hydrogen were mixed in a cylinder open at one end exploded by means of a spark. This cycle was repeated at regular intervals. With increasing frequency, the explosions would stop and the gas would burn as in a jet flame.

It was found that the hydrogen had to be injected into the oxygen through capillary openings in order to prevent the flame from continuing after the explosions and setting fire to the next gas charge.

Rare mixtures were easier to keep up the explosions than were the richer ones. Thirty-six explosions per second were made as our top limits simply because the mechanical valves could not run any faster.

PSYCHOLOGY

Chairman: H. H. REMMERS, Purdue University

Professor W. N. Kellogg, Indiana University, was elected chairman of the section for 1945.

An harmonic analysis study of hoarse and non-hoarse voice quality. DAVID T. HERMAN, Indiana University.—The differences in harmonic energy distributions of the vowel "o" (as in pot) of fifteen university students classed subjectively as having hoarse voices and fifteen classed as having non-hoarse voices have been studied. Oscillographic recordings of the vowel of each subject and harmonic analyses of a single wave of each subject were made. Characteristic frequency regions (CFR) for the vowel of the male subjects were found as 630 to 880 dv. and 980 to 1400 dv.; for female subjects, as 800 to 1140 dv. and 1980 to 2600 dv. As groups both the male and female hoarse subjects showed greater energy outside the CFR than male and female non-hoarse subjects. In almost all subjects the fundamental was found to be a weak partial. Only in the female hoarse group was the fundamental relatively strong. The hoarse groups, on the average, showed greater energy in the first three partials. Female hoarse subjects showed greater energy in the first three partials than female non-hoarse subjects, with the fundamental for the hoarse being considerably stronger. Male hoarse subjects were slightly weaker in the fundamental than male non-hoarse subjects, but were stronger in the second, third and fourth partials. A simulated hoarse quality vowel spoken by a single subject showed the usual CFR, but the total composition of the vowel resembled neither that found in the naturally hoarse voice nor the non-hoarse vowel of the same subject.

A study of the ability of high school pupils to recognize and recommend principles of behavior development in emotionally-toned situations. ALMA LONG, Purdue University.—The problem was to discover the interest and ability of youths to deal with matters having great concern to themselves and for which some guidance might be needed. It was believed that such a study would reveal some pertinent general trends in the thinking about and feeling toward general and some specific problems which are commonly experienced by adolescents and also those which are exaggerated by the stress of wartime.

A large number of brief descriptions of problems having a definite emotional tone, which had been brought to high school teachers during the preceding year (1943) were classified and studied to find indication of the psychological needs which they represented. From these, a series of "situations" which might have been commonly experienced by high schol pupils was prepared for response by such youths. With each situation, there was a brief description of the psychological principle involved, and seven approaches to the problem involved. Of the seven,

four were agreed to be good methods, two were of negative value and one was neutral. The pupils were asked to select the best two and the poorest one of the methods. Items of personal information about the individuals who took the test provided many classifications for comparison of the choices made.

From these detailed analyses of 2,365 papers received from pupils in 36 schools in Indiana, ranging from 11 to 18 years in age and in grades seven to twelve, one-third of whom were boys, three types of findings resulted: 1. Evidence of trends which are common to very large groups, related to common problems, in which the widely scattered individuals expressed their endorsement of and demand for responsibilities which are suited to their abilities and interest, need for opportunities to assume their place in a responsible and responsive group and suitable practice in the training needed; recognition of the fact that visible behavior is often very different from the feelings which underlie it; and that attitudes toward people change upon better acquaintance.

2. Significant differences in choices made were related to age and sex, level of intelligence, quality of the home environment of the child, personality characteristics of the individual noted in the records of the individual and his place among members of his social group, and with reference to his known behavior history. There were also specific differences in the ease with which relationships were seen between psychological principles and their counterparts in behavior. These latter outline some areas in which further instruction could well be given.

3. Evidence of the ability of high school children of all ages to understand and to apply many important psychological concepts to the interpretation of emotional behavior, and also of their recognition of the values accruing to themselves from better understanding of human behavior.

The wide distribution of salient responses among those of the entire group point out that eleven years is certainly not the lowest age level at which important learnings about human behavior occur, and that many attitudes have already formed either for or against the most desirable social adjustment of young people. Comparable group responses indicate some fundamental differences in the views and practices of the sexes, some traits which are common to both, but which are subject to modification with growth, some which are related to advantages of intelligence, and some which result from the quality of home environment. They also indicate that the casual brushes of a youth among those of his own age level are not sufficient to ensure important learnings without some guidance and instruction, and that of all those general influences which were considered in the study, the benefits of membership in a superior home and family group was most productive of the specific understandings which contribute to fine relationships among people.

A new set of music tests. ROBERT W. LUNDIN, Indiana University.—The paper contains a description of five musical ability tests devised by the author. They are designed to measure such abilities as are commonly taught in music theory classes. They do not purport to meas-

ure any inherited traits since the author questions whether musical ability is inherited. From a statistical analysis of the tests which were given to a group of music students and an unselected group of college students, the author believes that if properly revised the battery may be useful at getting at what is commonly known in music circles as "musicality."

Preservation in normal speakers and stutterers. HARRIS HILL, Indiana University.—This study partially tested the hypothesis that perseveration of action occurs if well-learned serial behavior is interrupted. The testing was accomplished by recording the behavior which resulted from the blocking of a secondarily-automatic sequence of movements involving paired musculatures. Normal speaking and stuttering subjects learned three movements in the form of serial activity to a point where little observational control was necessary. During the last test period, mechanical blocking of the sequence of movements was introduced at various intervals and in specific order. The general types of variable behavior studied were: Repetitions of movements, prolongations of movements, breathing abnormalities, reactions to anticipation, and omissions of movements. Twenty-one forms of variable behavior were measured in all. Among other reactions found, perseveration was present in the records of all subjects of both groups. Differences between normal speakers and stutterers mainly took the form of slower reactions for the stutterers (i.e. prolongation of movements), and the apparent inability of 50 per cent of the stutterers tested as against 20 per cent of the normal speakers tested to achieve the speed required in this experiment.

ZOOLOGY

Chairman: W. H. Headlee, Indiana University School of Medicine

Professor W. R. Breneman, Indiana University, was elected chairman of the section for 1945.

The trematode parasites of a species of Goniobasis from the Tippecanoe River, Indiana. R. M. Cable and Lois Kraus, Purdue University.—During September and October, 1944, 1,367 specimens of an undetermined species of *Goniobasis* were collected from Tippecanoe River and examined for larval trematodes. The incidences of infection, based on the spontaneous emergence of cercariae from the isolated snails, were as follows: two (0.15 per cent) were infected with a giant-tailed echinostomoid cercaria, probably a new species of larval psilostome; one (0.075 per cent) with a slender-tailed psilostome cercaria; one (0.075 per cent) with a pleurolophocercous form; two (0.15 per cent) with *Cercaria megalura* Cort; three (0.22 per cent) with a notocotylid monostome cercaria; three (0.22 per cent) with a cotylomicrocercous form; five (0.37 per cent) with one of two species of xiphidiocercariae of the Pusilla type and 36 (2.63 per cent) with the other; seven (0.51 per cent) with one of two species of Virgula type xiphidiocercariae and 17 (1.24 per cent) with the other. Five additional snails were infected with stylet cercariae but died before final identification could be made. Both of the Virgula type xiphidiocercariae are new species being reported elsewhere and certain of the others may prove to be new upon further study.

Studies on four new species of xiphidiocercariae of the Virgula type (Trematoda: Digenea). Philip G. Seitner, Purdue University.—Examination of prosobranch snails collected within a limited radius of Lafayette, Indiana, has revealed the presence of four new species of xiphidiocercariae of the Virgula type, in addition to the single species reported by the writer a year ago. This makes a total of six species of Virgula cercariae reported from the United States. All Indiana species have the same number of cephalic glands (three pairs), but differ in the arrangement of their ducts, size of body and Virgula organ, and shape and size of the stylet. There also are differences in spination, particularly in respect to the tail which is aspinose in one species, spinose with slightly larger spines at the tip in two species, and aspinose except the tip in the remaining species. One occurs in a species of *Pleurocera* collected from Eel River, near North Manchester, and another in the same host species taken from the Tippecanoe River. The two remaining cercariae develop in a species of *Goniobasis* from the Tippecanoe River. A fifth species found in *Goniobasis livescens* from Wea Creek may be identical with the one hitherto reported from McCormick's Creek.

Notes on the incidence, biology and medical importance of parasites of man in Indiana. WILLIAM HUGH HEADLEE, Indiana University Medical Center.—Records show that a considerable number of animal parasites of man are present in Indiana, including some Arthropods that are important in the transmission of parasites or other disease agents, and/or that are of importance because of their role as ectoparasites or pests of man. Stools were examined from 2,875 individuals, and the percentage incidence of the intestinal parasites found are given in parentheses following the name of the organism. Protozoa recorded were *Endamoeba histolytica* (1.2), *Endamoeba coli* (36.8), *Endamoeba gingivalis, Iodamoeba bütschlii* (2.6), *Giardia lamblia* (3.2), *Chilomastix mesnili* (2.6), *Trichomonas hominis* (0.14), *Trichomonas vaginalis, Plasmodium vivax,* and *Plasmodium falciparum.* The helminths recorded were *Ascaris lumbricoides* (0.14), *Trichuris trichiura* (0.17), *Necator americanus* (0.1), *Strongyloides stercoralis* (0.9), *Enterobius vermicularis* (3.3 by stool examination; 16.9 of 295 individuals from which perianal scrapings were examined), *Hymenolepis nana* (0.14), *Taenia spp.* (0.07), *Diphyllobothrium latum* (2 cases) and *Dipylidium caninum* (1 case). In addition, one infection each of *Schistosoma mansoni* and *Clonorchis sinensis* were found, but these were not native cases.

A list of the more important Arthropods found in Indiana is presented including the following: *Diaptomus oregonensis, Cyclops prasinus, Cyclops viridus brevispinosus, Lithobius forficatus, Latrodectus mactans, Dermacentor variabilis, Trombicula irritans, Pediculoides ventricosus, Pediculus humanus capitis, Pediculus humanus corporis, Phthirius pubis, Sarcoptes scabiei, Cimex lectularius, Anopheles quadrimaculatus, Anopheles punctipennis, Culex pipiens, Aedes aegypti, Sarcophaga hemorrhoidalis, Sarcophaga bullata, Oestris ovis, Lucilia sericata, Chrysops sp., Pulex irritans,* and *Xenopsylla cheopis.*

Data are presented concerning the occurrence in Indiana of some of the diseases caused by helminths, protozoa, rickettsiae and viruses which are transmitted by Arthropods or for which Arthropods serve as an intermediate host.

Further observations on factors influencing hypoxic resistance in mice. WM. A. HIESTAND and HELEN ROGERS MILLER, Purdue University.—The effects of such factors as rate of barometric decompression, carbon dioxide, starvation, carrot diet, dehydration, and air temperature on hypoxic survival of mice have been investigated. Our results have demonstrated the following facts, some of which are corroboration of earlier work, others of which are unique.

Mice tolerate hypoxia best if decompressed slowly (approximately 674 feet per·second as an average). Prolonging the rate too greatly results in earlier failure of the mice.

Carbon dioxide has no significant effect on hypoxic survival not being beneficial to greater tolerance.

Inanition decreases hypoxic resistance in direct proportion to the duration of the starvation.

An exclusive diet of carrots for 10 days increases the resistance of

mice to anoxia which is apparently related to water loss from the tissues. Dehydration up to approximately 20 per cent of total body weight significantly increases hypoxic resistance, beyond 20 per cent diminishes resistance.

Reduction of the temperature of the surrounding air increases hypoxic resistance in direct proportion as the air temperature is lowered.

It is likely that dehydration as well as lowering of external air temperature decrease the rate of metabolism of the mice thereby increasing hypoxic resistance.

Effects of spatial restriction upon defensive fighting of male mice. J. P. SCOTT, Wabash College.—Untrained adult males of the C-57 strain of mice were subjected to severe attacks by trained fighters of the same strain, first in large multiple escape pens and later in small boxes, for periods of 30 minutes each. In accordance with previous observations, it was expected that the type of defensive behavior would vary with the amount of escape room. The defensive behavior obtained can be classified as follows, in order of amount of activity: (a) fighting back, (b) running away, (c) defensive posture (standing on hind legs and holding front legs out toward aggressor) plus tail rattling, (d) defensive posture, squeaking when attacked and (e) lying on back with feet in air, squeaking when attacked. Types (b) and (d) were most commonly observed. Under these conditions the two interacting factors which appeared to determine the type of defensive reaction were (1) space and (2) severity and suddenness of the attack: (1) running away was associated with the large multiple escape pen, whereas the defensive posture was associated with the small pen. Lying on the back occurred when the mouse was caught in the end of a blind passage. (2) When the attack by the aggressor was sudden and severe, the attacked mouse did not fight back and might not be able to escape by running and so assume the defensive posture even in the large pen. — All types of behavior appeared to be adaptive, with the possible exception of squeaking. It is concluded that the behavior resulting from spatial restriction of defensive movements of untrained mice is in general adaptive.

The development of the gonads of the albino rat. THEODORE W. TORREY, Indiana University.—A gonadal blastema is established through the combined proliferative activities of a morphologically continuous coelomic epithelium and deeper mesenchyme. Ovarian differentiation begins on the 16th day with the appearance within the blastema of primary cords. There is no tunica between the cords and the epithelium. The primary cords either abut directly against the epithelium or are continuous with it. The epithelium in turn differentiates into superficial and basal layers, the latter, then, commonly being continuous with the cords beneath. Secondary cords originate in the basal epithelium, but are continuous with and thus not easily distinguished from the primary cords. Testes differentiate towards the end of the thirteenth day. Primary cords arise directly out of the gonadal blastema and an area of undifferentiated cells, potential tunica, intervenes between the cords and

coelomic epithelium. The subsequent history of the primary cords, germ cells, tunica, and interstitial cells parallels that for mammals in general. All are traced to the original blastema. The coelomic epithelium of the testis fails to differentiate into two layers as it does in the ovary. Further, no secondary cords are produced. A slightly greater thickness of the epithelium on the ventral surface of the testis is the only indication of a potential second generation of cords. These observations are discussed in terms of the general question of sex reversal.

Some birds of Indiana. HOWARD H. VOGEL, JR., Wabash College.—This 16 mm. kodachrome motion picture film shows a number of our Indiana birds in color. Efforts were made to secure pictures of characteristic behavior, especially different nesting habits, methods of feeding, types of flight, and the hatching process. A series of motion pictures show a roost of the Turkey Vulture near the "Shades" at Waveland, Indiana. These pictures emphasize the roosting habitat, the soaring flight of the birds, and their method of keeping their balance in the tops of dead trees. Another group of pictures shows a heron rookery at Mace, Indiana. Characteristic behavior is shown by our largest heron, the Great Blue Heron. Nesting is photographed in several other species, including the Mourning Dove, Red-winged Blackbard, Catbird, Ruby-throated Hummingbird, House Wren, Bluebird, Flicker, Wood Thrush, and Chipping Sparrow.

A series of time lapse photographs show the hatching process in the eggs of the Bobwhite Quail. Other pictures show characteristics of immature birds. Several different methods of feeding are also shown in these films, especially of the Mallard Duck and the Horned Lark.

A Summary of Bird-Banding Activities from April, 1941, to November, 1944

(REV.) JOHN W. BAECHLE, St. Joseph's College

In the spring of 1937 a Government Cooperative Bird-banding Station was started at St. Joseph's College, Collegeville, Indiana. During the first four years of its operation over 300 birds were banded and a number of these birds were recaptured a year or two later, either at our station or at some distance from our station. Then in April, 1941, I took over the management of this station, and since that time, with the aid of several of my biology students, have banded 6,308 new birds of 67 different species. Of these there were 14 species of which only a single bird was banded. These birds were:

Virginia Rail
Sora
Broad-winged Hawk
Yellow-bellied Sapsucker
Red-headed Woodpecker
Migrant Shrike
Red-eyed Vireo
Cape May Warbler
Magnolia Warbler
Louisiana Water Thrush
Northern Yellow-throat
Yellow-breasted Chat
Wood Thrush
Gray-cheeked Thrush

There were also 25 species of which between one and ten birds were banded. They were:

Quail	5
Screech Owl	2
Yellow-billed Cuckoo	3
Belted Kingfisher	9
Downy Woodpecker	6
Ruby-throated Hummingbird	4
Kingbird	6
Crow	7
Baltimore Oriole	8
Tree Sparrow	5
Chipping Sparrow	6
Lincoln Sparrow	8
Myrtle Warbler	4
Black-throated Green Warbler	2
Ovenbird	3
Mockingbird	4
Winter Wren	3
Brown Creeper	5
White-breasted Nuthatch	5
Black-capped Chickadee	9
Ruby-crowned Kinglet	8
Veery	2
Olive-backed Thrush	5
Hermit Thrush	2
Bluebird	4

There were 19 species of which from 10 to 100 individuals were banded, as follows:

Kildeer	18
Barn Owl	11
Flicker	37
Chimney Swift	16
Cowbird	26
Swamp Sparrow	63
Fox Sparrow	11
Red-eyed Towhee	29
Cardinal	64
Indigo Bunting	14

Red-winged Blackbird 43
Bronzed Grackle 52
White-crowned Sparrow 41
Field Sparrow 49
Song Sparrow 73
Catbird 56
Brown Thrasher 57
Tufted Titmouse 10
Golden-crowned Kinglet ..... .22

Of the following 6 species there were from 100 to 1,000 individual birds banded:

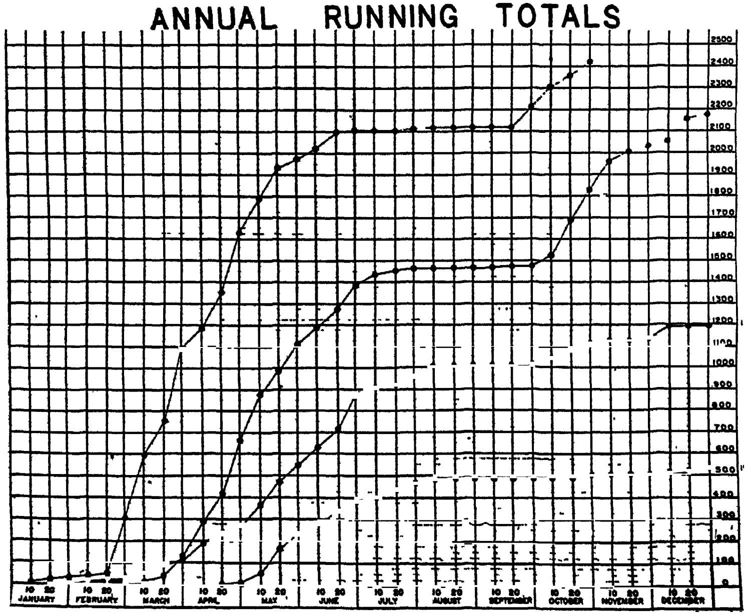
Mourning Dove 228
Blue Jay 117
Purple Martin 267
Barn Swallow 215
House Wren 253
Robin 662

Finally, there were 3 species of which over 1,000 birds were banded. They were:

Starling 1,101
White-throated Sparrow 1,400
Slate-colored Junco 1,251

The chart illustrated in Fig. 1 shows the total number of birds banded year by year. This chart is brought up to date on the 1st, 10th and 20th of each month. In this way a fairly accurate comparison can be made between the total number of birds banded up to any date of any year recorded on it. The spring migration period followed by the nesting season, during which large numbers of nestlings are banded, always shows an abrupt rise in the graph. The later summer months usually

BIRDS BANDED AT ST. JOSEPH'S COLLEGE, ANNUAL RUNNING TOTALS



show little activity because few birds nest so late and not many birds are trapped due to the abundance of natural bird food during this time. The fall migration, especially of White-throated Sparrows and Slate-colored Juncos, likewise produces a sudden rise each year. The exceptionally large increase in birds banded during December, 1943, and February and March, 1944, was due to our banding of over 900 Starlings which winter on our campus. These birds were caught in our barns and silos at night with the aid of flashlight and net.

In the following summary of REPEATS, RETURNS, and RECOVERIES, it is well to bear in mind the specific meaning given to these terms in the banding of birds. A bird is called a REPEAT when it is caught at the same station within three months of its previous capture there. The presumption is that it has been in the locality all the time. A bird is called a RETURN when it is captured, (or found dead) at the station where it was originally banded, but after more than three months have elapsed since its previous capture. The presumption is that it had migrated to some distance from the station and returned. A bird is called a RECOVERY when it is captured, (or found dead) at some distance from the place where it was banded. It is in the above meaning that these terms are used in the following table:

Year	Newly Banded	Repeats	Returns	Recoveries	Number of Species
1937 to 1941	308	Not recorded	5	8	Not included
1941	528	154	11	3	29
1942	1192	285	28	2	44
1943	2173	909	27	4	46
1944 (Up to Nov)	2435	746	38	5	41
Totals	6636	2094	109	22	67 (Excluding duplicates)

It is of special interest to note that 49% of the REPEATS were White-throated Sparrows, and 26% of the REPEATS were Slate-colored Juncos. It is also noteworthy that 18% of the RETURNS and 68% of the RECOVERIES were banded as nestlings. As a rule the banding of nestlings is frowned upon if not discouraged because of the low percentage of RETURNS and RECOVERIES usually obtained from banded nestlings.

The 109 RETURNS recorded at our station were made by 95 individual birds of the following 16 species:

Blue Jay	31	Song Sparow	3
Purple Martin	14	Slate-colored Junco	3
Catbird	8	Downy Woodpecker	2
Brown Thrasher	7	House Wren	2
Starling	8	Bronzed Grackle	2
Robin	5	Mourning Dove	1
Cardinal	4	Swamp Sparrow	1
Tufted Titmouse	3	Cowbird	1

The difference between 109 RETURNS and 95 birds accounting for the RETURN records, lies in the fact that several individual birds returned on more than one occasion. They are as follows: 3 of the above Purple Martins, and two each of the following species returned to our station on two consecutive years, Catbird, Brown Thrasher and Blue Jay. There was one particular Blue Jay which returned during three consecutive years, and one Cardinal which returned four times.

As to the RECOVERIES, 13 of the 22 were found in either Indiana or Illinois. The following table gives the place of recovery, species, age when banded, and interval between the date of banding and the date of recovery of the birds, as well as the cause of death of the recovered birds:

Location	Species	Age	Interval	Cause of death
Indiana and Illinois				
1) Rensselaer, Indiana	Blue Jay	Adult	19 months	Shot
2) Near Rensselaer, Indiana	Bronzed Grackle	Adult	12 months	Shot
3) Francesville, Indiana	Broad-winged Hawk	Adult	2 weeks	Shot
4) Newland, Indiana	Mourning Dove	Nestling	31 months	Found dead
5) Kouts, Indiana	Bronzed Grackle	Nestling	13 months	Found exhausted and later died
6) Hobart, Indiana	Purple Martin	Adult	3 weeks	Found dead
7) Elmhurst, Illinois	Flicker	Nestling	11 months	Killed by flying into a window
8) Blue Island, Illinois	Red-winged Blackbird	Nestling	6 months	Found injured and later died
9) Monee, Illinois	House Wren	Nestling	13 months	Found dead
10) Victoria, Illinois	Robin	Nestling	12 months	Found dead
11) Tolono, Illinois	Starling	Adult	$3\frac{1}{2}$ months	Found dead
12) Paris, Illinois	Barn Swallow	Nestling	5 weeks	Found dead
13) Danville, Indiana	Mourning Dove	Nestling	$13\frac{1}{2}$ months	Found dead
Outside Indiana and Illinois				
1) Perth, Ontario, Canada	Starling	Adult	7 months	Found dead
2) Springfield, Ohio	Barn Owl	Nestling	4 months	Shot
3) Boynton, Florida	Mourning Dove	Nestling	20 months	Shot
4) Palm Harbor, Florida	Robin	Nestling	21 months	Shot
5) Nicholls, Georgia	Flicker	Nestling	17 months	Shot
6) Gray, Georgia	Robin	Nestling	22 months	Found dead
7) Brandon, Mississippi	Rusty Blackbird	Adult	7 months	Killed
8) Jeanerette, Louisiana	Robin	Nestling	9 months	"Found"
9) Osborn, Missouri	Barn Swallow	Nestling	22 months	Caught and released while nesting

It might be well to note that the smaller sized birds, such as White-throated Sparrows, Juncos, House Wrens and Barn Swallows, although banded in large number, are seldom recovered. Because the birds are small, and their bands likewise small and inconspicuous, they are not so readily noticed when they die. If there were more bird-banders active in the southern states we might have more chance to obtain recoveries on these birds from their winter homes.

In conclusion, I might mention that in the past year I have begun to take close-up portraits of a number of the species which we catch, and 22 of these portraits are now on exhibit in room 330 of this building. You are invited to visit this display after this meeting.

Response of Chicks to Pituitary Gonadotropins and Pregnant Mare Serum[1]

W. R. BRENEMAN, Indiana University

The variation in the response of various vertebrates to anterior pituitary hormones is of considerable biological importance and in this laboratory we have been concentrating on avian studies of this type. There are some notable differences between bird and mammalian responses to gonadotropins. First, the luteinizing hormone, L.H. stimulates the interstitial cells of the rat testes and this is also accompanied by androgen secretion; in the chick, however androgen secretion is most marked when the seminiferous tubules are stimulated by the follicle-stimulating hormone, F.S.H. (Greep et al., 1936; Fevold, 1937; Engle, 1929; and Breneman, 1935). Second, it is noteworthy that there is no augmentation reaction demonstrated by chick testes when mammalian F.S.H. and L.H. are administered (Breneman, 1936), or by squab testes, (Evans and Simpson, 1934). Chlorophyll, however, did appear to augment pituitary gonadotropin when injected in the chick (Breneman, 1939b) but this was possibly a result of slower absorption of the hormone from pituitary-chlorophyll mixtures. These apparent differences emphasize a need for better understanding of the physiology of the avian gonads.

Earlier reports on the striking response of bird gonads to pregnant mare serum were accompanied by the suggestion that this substance was purely a follicle-stimulating principle. However it was demonstrated (Breneman, 1936) that the testes of chicks which had been given P.M.S. showed both F.S.H. and L.H. effects as measured by tubule and intertubular tissue development. Rowlands and Williams (1941) and Bates and Schooley (1942) likewise have indicated that in the rat the evidence favors the idea that two principles are present in pregnant mare serum.

The availability of more highly purified pituitary preparations in recent years and the improvement in testing techniques, especially the use of inanition experiments, suggested that a reinvestigation of the avian responses to anterior pituitary and anterior-pituitary-like hormones would be profitable. Previous work by Byerly and Burrows (1938) and by Breneman (1939b) indicated that small amounts of anterior-pituitary principle would elicit responses in chicks which were kept without any food or water for a test period of 72 to 96 hours. These animals also were much more uniform in their responses than were animals on a normal diet. This greater uniformity and sensitivity affords a better opportunity for determining the response to gonadotropins.

[1] Contribution No. 321 from the Zoology Department and No. 91 from the Waterman Institute, Indiana University.

Materials and Methods

All chicks used in these experiments were single comb White Leghorn cockerels. Injections were made subcutaneously into the dorsal neck region once daily in the longer series, or more frequently in the short series, as will be noted in the tables. The series referred to as "limited diet" were modified inanition experiments in which food was available only on alternate days. No food was given during the last twenty-four hours of any experiment. The 96-hour experiments were patterned after the Byerly and Burrows (1938) technique in which the chicks were kept in shipping boxes of four compartments each holding 25 chicks. Injections began when the birds were 12 hours old and the animals received no food or water during the period of treatment. The mortality seldom was more than 1% in spite of the severity of the inanition. The stored yolk apparently was able to sustain the animals. The following hormone preparations were used: pregnant mare serum, P.M.S.[2], follicle-stimulating hormone, F.S.H.[2], and luteinizing hormone, L.H.[2]. A total of 650 chicks was used in these experiments.

Pregnant Mare Serum: Two types of inanition experiments were performed with P.M.S. The series were terminated at either the fifteenth or twentieth day after hatching in the first instance or a ninety-six hour test was performed. All dosages used were in terms of international units of the hormone (I.U.). The results of the longer experiments are presented in table I.

It is evident that in the 15-day series dosages of pregnant mare serum ranging from 2.5 I.U. to 40 I.U. had no significant effects on comb or gonad weights of the chicks. Injection of 40 I.U. of P.M.S. however, did produce increases in both comb and gonad weights but these were short of significant. The results suggest that 40 I.U. is near the threshold for the preparation in these experiments. Since this dosage is relatively high, it was hoped that a better response would result if the time of the experiment were extended to twenty days. The results of this experiment appear in the second part of table I.

The administration of 1 I.U. daily (total 16 I.U.) had no appreciable effect on the comb size or gonad size. Although dosages of 32 I.U. and 48 I.U. increased comb weights, the gonad weights were significantly increased in only the 48 I.U. series. It must be concluded that the longer injection period was probably the better, but the actual percentage increase over the controls produced by 48 I.U. was very little in excess of that which followed the injection of 40 I.U. in the shorter series. The longer series was, therefore, a doubtful technical improvement affording evidence only of an increase in secretory activity of the gonads. It must be concluded that the "limited diet" assay which was an efficient test for

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[2] The author wishes to acknowledge the kindness of Dr. George F. Cartland, Upjohn and Company, for the supplies of pregnant mare serum, Doctors R. O. Greep, H. B. VanDyke, and B. F. Chow, of the Squibb Laboratories, for the Metakentrin and Thylakentrin, and to Dr. J. P. Schooley, Director of Endocrine Research, Difco Laboratories, for the F.S.H. and L.H. (Difco) used in these experiments.

androgens (Breneman, 1942), is not very effective as a test for pregnant mare serum.

Previous experience has indicated that the 96-hour injection technique is a more sensitive assay in the chick than longer treatments. Three groups of experimental animals were used and these were given P.M.S. in one, three, and five injections. The controls were injected with distilled water in comparable fashion. The literature indicates that P.M.S. probably is not excreted in the rat, possibly due to the large size of the molecule and that multiple injections are no more efficacious than single administrations of the hormone; (McShan and Meyer, 1941; Meyer and McShan, 1941). It was observed in our experiments with chicks that multiple injections were much more effective. This is in harmony with a similar observation made previously concerning testosterone-propionate in which greater responses were produced by multiple injections (Breneman, 1939a).

An analysis of the data in table II reveals several important facts. As was indicated, the multiple injections were more effective at all dosage levels than a single injection of hormone. It is of considerable import that even 1 I.U. of P.M.S. produced significant increases in gonad weight when given in three or five divided doses but a single injection of 1 I.U. did not produce a significant increase. Administration of 2 I.U. in a single injection, however, did increase the testis weight to a significant level. It is also noteworthy that the gonads were larger at every dosage level of the hormone in the five injection series than in the three injection group. Furthermore, the marked plateau in response in the series given one or three injections was not evident at these dosage levels in the experiment which received five administrations of the P.M.S.

It was encouraging to observe the marked response of the gonads to the pregnant mare serum at these dosages, especially in view of the low standard errors observed. This test shows considerable promise for the assay of total gonadotrophic content of a preparation but, of course, does not furnish any evidence of a qualitative nature. It is probably safe to say, however, that the 96-hour test is from thirty to forty times more sensitive than the longer tests shown in table I. The physiological basis for this greater sensitivity is undoubtedly due to several factors, chief among which is the probability that there is no endogenous gonadotrophin present in these chicks. The White Leghorn may secrete minute amounts of pituitary hormone immediately after hatching, but the severity of the inanition reduces this pituitary activity. The response of the birds is, therefore, not complicated by variations in the amounts of endogenous hormones and this is reflected in lower standard errors. Likewise the fact that the chicks are confined in a small area and are less active would probably result in a slower rate of hormone absorption and utilization.

Follicle stimulating and lutenizing hormone—"96-hour test". The amounts of L.H. and F.S.H. injected into chicks are given in terms of rat units, R.U. The hormone was standarized on the basis of micrograms of nitrogen (Greep et al. 1942). A rat unit of the hormone was 2 μ gm. N. of L.H. and 5 μ gm. N. F.S.H. according to these determinations. These amounts, or multiples, were chosen for the chick tests and three injections

were made in a 96-hour period. Two groups of experiments were run and the controls, which were almost identical in range and standard error, were pooled. The data are presented in table III.

The effect of 1 R.U. of L.H. was barely significant but 1 R.U. of F.S.H. produced a very marked increase in gonad weight which was, however, accompanied by a greater variability. Two R.U. of L.H. was only slightly more effective than 1 R.U. and not significantly so. Good responses were also given by 2 and 4 R. U. of F.S.H. and some interesting comparisons can be made with the P.M.S. series. The 1 and 2 R.U. dosages of F.S.H. produced gonads which were almost identical in size to those produced by 4 and 8 I.U. of P.M.S. in the 5 injection series. This does not imply a qualitative similarity, but does indicate a remarkably uniform quantitative response to gonadotrophins in 96-hour chick series.

Perhaps the most interesting aspects of the data in table III are to be found in the series which were given F.S.H. and L.H. simultaneously. F.S.H. was administered at two dosage levels of 1 and 2 R.U. each with 1 R.U. of L.H. The response in both instances was greater than that produced by the F.S.H. when given separately. Most interesting, however, was the fact that the responses were within the range of expected additive weights for the L.H. and F.S.H. treatments when the hormones were given separately. Obviously this demonstrates that no augmentation occurred.

F.S.H. and L.H. "older chicks": Relatively heavy dosages of F.S.H. and L.H. (Difco) produced significant increases in comb and gonad weights of 15-day old chicks. These chicks, as well as those in the 20-day series, were not up to the normal weight for chicks of this age but should probably not be considered as limited-diet birds. A total of 20 R.U. of L.H. produced an 80% increase in the gonad weights of the chicks accompanied by more than a 100% increase in comb weight. The administration of 10 and 20 R.U. of F.S.H. likewise increased both comb and gonad weights but in neither instance was the increase as great as that which occurred in the L.H. series. A combination of the two hormones at the 2 R.U. dosage level increased both comb and gonad weight but the effect was less than the additive effect of each when given separately. This was especially noteworthy for the gonads, because the response was only slightly greater in these than that produced by the L.H. alone. This confirms the observation made in table III that combinations of F.S.H. and L.H. did not produce augmentation in the chick.

The series given F.S.H. (Thylakentrin) and L.H. (Metakentrin) shown in the second part of table IV proved to be disappointing. The fine response to small amounts of these substances which was shown in table III suggested that the dosage tried would be ample, but no significant increases were noted except in those chicks which were given the 0.2 R.U. F.S.H. plus 0.5 R.U. L.H. daily. Even in this series only the comb was increased in size, the gonad weights actually being slightly below the control figure. Since these results are comparable to the

observations on the 15- and 20-day P.M.S. series, the experiment adds additional weight to the observation that the 96-hour technique is greatly superior to the longer injection series.

Summary and Conclusions

Pregnant mare serum and pituitary gonadotrophins were injected into chicks at varying time intervals. Chicks which were kept without food or water during the test period from 12 to 96 hours after hatching proved to be very responsive. Injections of 1 I.U. of P.M.S. produced a positive increase in the gonad weight of chicks if given in three or five divided doses, but not if given in a single injection. Divided dosages of the pregnant mare serum were more efficacious in every instance than were the single injections; and the administration of the hormone in five injections was more effective than in three. Only the combs of chicks composing fifteen and twenty day series were increased in weight following the administration of pregnant mare serum and higher dosages were required than in the experiments of shorter duration. The 96-hour test was approximately thirty to forty times more sensitive than the longer assay.

Follicle stimulating hormones were also effective on chicks but showed no evidence of augmentation when combined with L.H. Small dosages of 0.2 R.U. of follicle stimulating hormone and 0.5 R.U. of luteinizing hormone daily were ineffective in 15-day chick experiments and the hormones gave good responses only at the relatively high dosages of 10 to 20 R.U. Comb growth was stimulated following the administration of each hormone. When combination injections were given there was again no evidence of any augmentation. The increases noted were essentially additive effects of the hormone.

It is concluded that chicks used for the 96-hour test are highly sensitive to pituitary gonadotrophin and to pregnant mare serum. There is no evidence of augmentation when relatively low dosages of the hormone are administered. Both F.S.H. and L.H. increased comb size in older birds.

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Table I

Effect of P.M.S. on comb and gonad weights in "limited-diet" chicks

Treatment P.M.S. daily I.U.	No. of chicks	Body gm.	Comb mg.	Gonad mg.
	15-day series: injections 4th to 13th day			
(Controls)	13	55.5	14.2 ± 1.17*	11.0 ± 0.56*
0.25	14	56.6	14.2 ± 0.94	11.0 ± 0.71
0.5	16	57.8	16.8 ± 0.95	10.5 ± 0.47
1.0	14	56.9	13.4 ± 1.12	11.0 ± 0.58
2.0	16	58.2	15.5 ± 1.40	11.0 ± 0.89
4.0	13	54.7	17.9 ± 2.54	13.9 ± 1.30
	20-day series: injections 4th to 19th day			
(Controls)	20	75.0	27.3 ± 1.87	24.0 ± 1.19
1.0	13	78.5	28.0 ± 3.71	23.7 ± 2.54
2.0	9	76.5	40.1 ± 8.30	26.1 ± 3.65
3.0	10	89.8	51.7 ± 9.26	31.3 ± 3.65

Chicks received food only on alternate days. Injections were given in 0.20 cc. of water.

* Standard error.

Table II

Effect of P.M.S. on gonad weights of chicks in "96-hour test"

Treatment (Total Dosage) P.M.S. I.U.	No. of chicks	Body gm.	Gonad mg.
	Single injection 12 hours after hatching		
1	15	26.3	4.9 ± 0.41*
2	15	27.7	6.0 ± 0.32
4	14	26.9	6.9 ± 0.41
8	14	26.5	5.9 ± 0.30
10	15	27.9	7.2 ± 0.50
	Three injections: 12, 36, and 60 hours after hatching		
1	11	30.8	6.6 ± 0.38
2	14	30.6	7.0 ± 0.55
4	14	28.8	8.1 ± 0.74
8	14	29.1	7.7 ± 0.55
	Five injections: 12, 24, 36, 48, 60 hours after hatching		
1	12	31.3	7.2 ± 0.58
2	15	31.5	7.5 ± 0.60
4	15	31.0	9.4 ± 0.94
8	14	29.8	11.4 ± 0.42
Controls	40	28.0	4.6 ± 0.22

Chicks were kept in shipping boxes, 25 chicks in each of four compartments. All injections were in 0.20 cc. of water.

* Standard error.

Table III

Effect of F.S.H. (Thylakentrin) and L.H. (Metakentrin) on gonad weights of chicks in "96-hour test"

Treatment (Total Dosage)	No. of chicks	Body gm.	Gonad mg.
1 R.U. L.H.	25	39.8	7.7 ± 0.36*
2 R.U. L.H.	10	41.1	8.1 ± 0.66
1 R.U. F.S.H.	15	37.1	9.3 ± 0.47
2 R.U. F.S.H.	15	37.4	11.3 ± 0.42
4 R.U. F.S.H.	10	40.3	15.6 ± 1.70
1 R.U. F.S.H. plus 1 R.U. L.H.	22	35.0	10.4 ± 0.28
2 R.U. F.S.H. plus 1 R.U. L.H.	9	34.8	12.9 ± 1.21
Controls	32	32.6	5.4 ± 0.25

Chicks were kept in shipping boxes, 25 chicks in each of four compartments. All injections were in 0.20 cc. of water.

* Standard error.

Table IV

Effects of pituitary hormones on 15- and 20-day-old chicks

Treatment (daily)	No. of chicks	Body gm.	Comb mg.	Gonad mg.
15-day series—injections from 5th to 14th days				
Controls	18	77.1	30.8 ± 4.6*	21.9 ± 1.7*
2 R.U. L.H.	17	82.6	67.2 ± 10.0	39.6 ± 3.2
1 R.U. F.S.H.	18	87.7	41.9 ± 2.9	28.8 ± 3.6
2 R.U. F.S.H.	17	87.2	48.0 ± 7.1	38.8 ± 2.4
2 R. U. F.S.H. plus 2 R.U. L.H.	19	90.2	88.1 ± 12.2	45.2 ± 4.1
20-day series—injections from 4th to 19th days				
Controls	11	101.6	48.9 ± 12.9	30.5 ± 3.9
0.2 R.U. F.S.H.	9	87.1	37.1 ± 8.1	28.1 ± 3.8
0.5 R.U. F.S.H.	13	86.6	41.7 ± 9.0	25.9 ± 3.9
0.8 R.U. F.S.H.	10	93.1	40.8 ± 7.1	31.6 ± 3.8
1.0 R.U. L.H.	10	85.6	28.4 ± 5.2	23.2 ± 3.4
0.2 R.U. F.S.H. plus 0.5 R.U. L.H.	10	84.4	57.5 ± 21.3	27.8 ± 5.9

All injections were in 0.20 cc. of water.

* Standard error.

Pharmacological Action of Morphine on the Red Fox, *Vulpes fulva*

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Since the isolation of morphine from opium by Sertürner (1) its effects on various animals and on isolated organs have been studied by many. Probably no other drug has been so widely investigated. Even Claude Bernard (2) investigated its effects on the cat, rabbit, rat, guinea pig, dog, pigeon, and frog. He came to the conclusion that its action was similar on all of these species with "due allowance being made for the sensibility of the animals operated upon." Thus he failed to notice its excitatory effect on cats and its diphasic action on animals in general. The only animals showing no pharmacological reactions to morphine are the invertebrates. The excellent comprehensive summary of the works on the opium alkaloids by Krueger, Eddy, and Sumwalt (3, 4) give no reference to the effects of morphine on the fox. At least fifteen species of mammals other than man have been used. Foxes in some behavior characteristics resemble both dog and cat and because morphine affects those species in essentially opposite ways we thought it interesting to determine the pharmacological response of the fox to morphine.

Morphine exhibits a diphasic action being depressant as well as stimulant. The degree of depression is presumably proportional to the degree of cerebral organization and therefore man shows the highest degree of depression while animals lower than the primates, monkeys, and dog exhibit primarily excitatory effects. In general it depresses the cerebral cortex and stimulates the cord. The Straub mouse-tail reaction (5) is typically characteristic of the stimulant action of morphine.

Dogs show an initial depression followed by increased reflex excitability of the cord. The usual dosage for dogs is 10 mg. per kilo which produces light sleep and muscular relaxation and facilitates inhalation anesthesia.

Cats show excitement to morphine becoming convulsive when frightened. No depression is apparent although Guinard (6) has stated that morphinized cats are more susceptible to chloroform narcosis than are non-morphinized ones.

A summary of the species effects of morphine on various animals can be made as follows:

A. **Those showing primarily depression:** man, chimpanzee, monkeys, dog.

B. **Those showing primarily stimulation:** frog, mouse, rat, guinea-pig, rabbit, horse, ass, sheep, goat, pig, cat, lion, tiger, panther, bear, marmot, hedgehog.

Birds (chicken, duck, sparrow, and pigeon) are relatively insensitive to it. With small doses they are depressed, with lager doses excited. It

should be pointed out that the above classification is questionable because of the possibility of the existance of two doses, one causing primarily stimulation and the other depression. This has been aptly demonstrated by Tatum, Seevers, and Collins (7) for the monkey, *Macacus rhesus*, for which there are two lethal doses, one causing death by depression, the other by convulsion.

Experimental: Two adult red foxes, *Vulpes fulva,* one of which had veen ovariectomized some months previously, were each injected with 32 mgm. of morphine sulphate intramuscularly. Both of these animals had become quite wild and were handled with a snare at the end of a long brass tube. The morphine effects became apparent in about 10 minutes and are shown in the following protocol:

10-15 minutes: loss of hind leg coordination, ataxia, excessive salivation, tongue extended beyond front teeth even while mouth was kept closed in jaw spasm, muscular tone increased, no evidence of atonia of legs or abdomen.

15-30 minutes: head sagged as foxes lay in crouching position, poor coordination in balancing on board 4 inches wide above ground, easily handled with no attempt to bite or struggle.

60 minutes: tongue excessively dry, evidence of beginning recovery, some ambulatory activity.

360 minutes: hyperirritable but still psychically depressed, good auditory acuity, hyperesthetic to sounds such as snapping of the fingers.

Thus the fox shows both psychic depression and hypertonicity. Early ptyalism is followed by antisialogogic action. Muscle tonus is exaggerated simultaneously with a tendency toward narcolepsy. Morphine causes less depession in the fox than in the dog for equal doses per unit of weight or in other words the fox falls lower in the scale than the dog to morphine but not as low as the cat.

Conclusions

Morphine causes psychic depression and spinal hypertonicity in the red fox, *Vulpes fulva.* Depression is less in the fox than in the dog where spinal excitability is greater putting the fox lower than the dog but higher than the cat in the morphine series.

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The Distribution and Relative Seasonal Abundance of the Indiana Species of Cordulidae and Libellulidae (Odonata)

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The relative seasonal abundance of the adults of the Indiana species of the Agrionidae, based upon the frequency of records for 41 years (1900-1940 inclusive) has been indicated in previous papers (Montgomery, 1942, 1944). A similar summary of the records for the Cordulidae and Libellulidae is presented here.

Records of captures (or observations), preserved in note books of the late E. B. Williamson and of the author, were tabulated by thirds of months and a time-frequency graph for each species was constructed by plotting the frequency for each third at the midpoint (5th, 15th, and 25th of the month respectively). These graphs, formed into two charts (Fig. 1 and 2) show the relative abundance of the different species throughout the recorded season of flight (adult life).

Fifteen species of Cordulidae and 33 species of Libellulidae have been recorded from Indiana. One of these, *Neurocordulia obsoleta* (Say), was not recorded from Indiana during the period of this study, or in fact, since the time of the original description, although it has been found a few times in neighboring states. Three other species of Cordulidae and one of Libellulidae were each recorded in only one year during the period of 1900 to 1940 inclusive. No species was recorded for all of the 41 years; *Libellula pulchella* Drury was reported for 38 years, *L. luctuosa* Burmeister for 36, and three other species for 33 years each. The number of species of these two families recorded each year has varied from three, in 1923, to 25, in five different years; the average number per year has been approximately 18, of which 14.5 were Libellulidae, 3.5 Cordulidae. No Cordulidae were recorded during three years, 1916, 1920, and 1923, and only one species in each of four years; the greater numbers of species of this family to be reported was nine, in 1922. Only three species of Libellulidae were taken in 1923, and only four in 1918; the greatest number of species of this family to be recorded in any year was 20, in both 1914 and 1927. The number of years in which each species was found is indicated immediately following the species name in the list below.

List of Species with Notes on Distribution and an Indication of the Number of Years Each Species Was Collected from 1900 to 1940 Inclusive

Cordulidae

Didymops transversa (Say)—7; Maritime Provinces and Michigan to Florida and Oklahoma.

Macromia georgina (Selys)—1; Indiana to North Carolina, Georgia, and Texas. *M. illinoiensis* Walsh—13; Nova Scotia and Wisconsin to South Carolina and Kansas. *M. pacifica* Hagen—14; Ohio, Wisconsin, and Nevada to Texas and California. *M. taeniolata* Rambur—18; New York, Wisconsin, and Kansas to Florida and Oklahoma. *M. wabashensis* Williamson—7; Wells County, Indiana.

Epicordulia princeps (Hagen)—25; Maine, Quebec, and North Dakota to North Carolina and Texas.

Neurocordulia obsoleta (Say)—0; Maine and Michigan to North Carolina and Louisiana.

Tetragoneuria cynosura (Say)—21; Maine, Quebec, and Minnesota to Florida and Louisiana. *T. simulans* Muttkowski—10; Maritime Provinces and Wisconsin to North Carolina and Indiana. *T. spinigera* Selys—1; Maritime Provinces and British Columbia to Connecticut, Indiana, and California.

Dorocordulia libera (Selys)—4; Maritime Provinces, Quebec, and Wisconsin to New Jersey and Indiana.

Somatochlora ensigera Martin—7; Manitoba and Saskatchewan to Indiana, Oklahoma, and Colorado. *S. hineana* Williamson—0; Logan County, Ohio. *S. linearis* (Hagen)—15; Maine, Quebec, and Illinois to Georgia and Missouri. *S. tenebrosa* (Say)—4; Nova Scotia, Quebec and Illinois to South Carolina and Tennessee.

Libellulidae

Libellula cyanea Fabricius—24; New Hampshire and Kansas to Georgia and Oklahoma. *L. julia* Uhler—2; transcontinental, Quebec and Connecticut to British Columbia. *L. incesta* Hagen—19; Maine and Wisconsin to Florida and Oklahoma. *L. luctuosa*—Burmeister—36; Maine and North Dakota to Florida and northern Mexico. *L. vibrans* Fabricius—10; Maine and Wisconsin to Florida and Oklahoma. *L. quadrimaculata* Linné—5; circumpolar; in the Old World, England and Spain to Japan; in the New World, Newfoundland and Alaska to North Carolina and California; northern Indiana is probably the southern limit of the range outside of the mountains. *L. semifasciata* Burmeister—12; Maine and Wisconsin to Florida and Texas. *L. pulchella* Drury—38; transcontinental, Quebec and British Columbia to Florida and California. *L. lydia* Drury—32; transcontinental throughout southern Canada and the United States.

Nannothemis bella (Uhler)—5; Maine and Michigan to Florida.

Erythrodiplax minuscula (Rambur)—2; Maryland and Oklahoma to Florida and Texas. *E. umbrata* (Linné)—1; Ohio and Indiana, through West Indies, Mexico and Central America, to Argentina.

Perithemis tenera (Say)—31; Massachusetts and Kansas to South Carolina and Mexico.

Erythemis simpliciocillis (Say)—32; Quebec and British Columbia to West Indies and Mexico.

Pantala flavescens (Fabricius)—17; circumequatorial and ranging to approximately 40° north and south. *P. hymenaea* (Say)—11; southern Canada to Chile.

Tramea carolina (Linné)—11; Massachusetts to Florida and Kansas. *T. lacerata* Hagen—29; Massachusetts and California to Florida and Mexico, Hawaiian Islands. *T. onusta* Hagen—10; Ohio and Nevada to West Indies and Mexico.

Sympetrum ambiguum (Rambur)—22; Massachusetts and Kansas to Georgia and Texas. *S. corruptum* (Hagen)—11; New England and British Columbia to Florida, Mexico, and British Honduras. *S. internum* Montgomery—1; Canada and Alaska to Indiana and California. *S. obtrusum* (Hagen)—28; Quebec and British Columbia to North Carolina and California. *S. rubicundulum* (Say)—33; Quebec and Wyoming to Maryland, Kentucky, and Nevada. *S. semicinctum* (Say)—7; transcontinental from southern Canada to North Carolina and California. *S. vicinum* (Hagen)—29; transcontinental in southern Canada, southward to North Carolina and Oklahoma.

Pachydiplax longipennis (Burmeister)—33; Massachusetts, Ontario, and Montana to Florida and Mexico; Bermuda and Bahama Islands.

Leucorrhinia frigida Hagen—3; Maine, Quebec, and Manitoba to Concenticut and Indiana. *L. intacta* (Hagen)—25; transcontinental in southern Canada, southward to New Jersey, Tennessee, and Nevada.

Celithemis elisa (Hagen)—32; Maine and Wisconsin to South Carolina and Oklahoma. *C. eponina* (Drury)—33; Massachusetts, Ontario, and North Dakota to Florida and Texas; Cuba. *C. fasciata* Kirby—2; Indiana and Oklahoma to North Carolina and Florida. *C. monomelaena* Williamson—12; Connecticut and Wisconsin to New Jersey and Missouri (Oklahoma?).

Kennedy (1928) studied the relation of evolutionary level to geographic and seasonal distribution in the Anisoptera. He found "a distinct tendency for primitive groups to reach their maximum number of species in cool regions while the insects of the modern groups reach their maximum number of species on the hot equator" and a tendency for "the most active insects to occupy the midseason while the less active or more primitive types occupy the early and late seasons." The data for Kennedy's study of seasonal distribution were obtained from Williamson's records to 1917, and, thus, consist of approximately the first half of the data summarized in the graphs of this paper. The groups used by Kennedy for comparisons were, for the most part, families.

Even with the present more complete seasonal data, few, if any, relations between evolutionary level and seasonal distribution, on a specific or generic level in the Cordulidae and Libellulidae can be deter-

mined. Too small a number of the total unit in a group—genera in a family, or species in a genus—are found in Indiana to provide a proper comparison. This is especially true if there is much relation between geographic distribution and evolutionary level, as the result of such correlation would be a homogeneous fauna within an area as small and uniform as that of the state. Furthermore, there has been little significant work on the relative evolutionary level of the genera of these two families, and, with a few exceptions, almost none on that of the different species of the several genera.

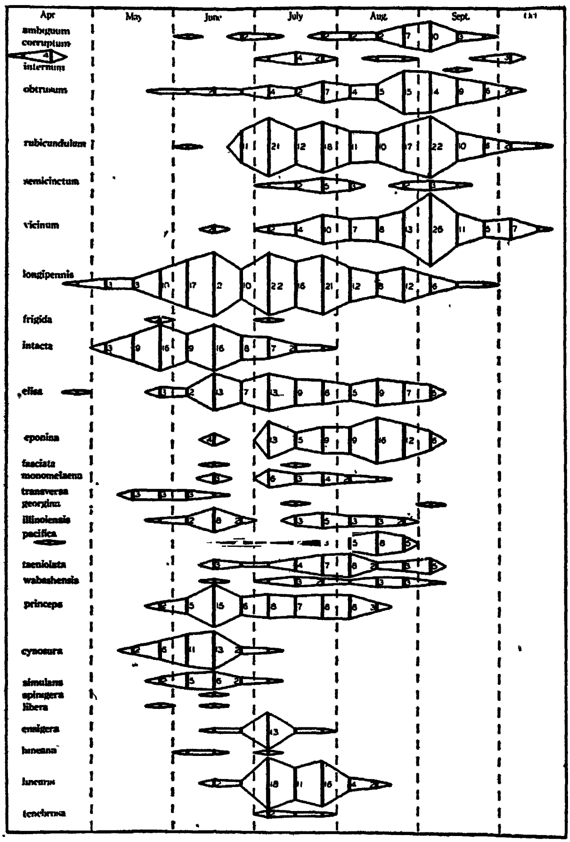

Fig. 1. The range of the flight season (or period of adult life) and the relative seasonal abundance of species of Libellulidae (genera Sympetrum, Pachdiplax, Leucorrhinia, and Celithemis) and of Cordulidae (genera Didymops, Macromia, Epicordulia, Tetragoneuria, Dorocordulia, and Somatochlora) in Indiana. Numbers near each bar indicate the number of collections of each species in each third of a month during the period of 1900 to 1940 inclusive; where no number is given the number of collections is one. The range for *S. vicinum* extends beyond the limit of the chart; there were two collections in the first third of November and one collection in each of the other thirds of that month.

Of the seven genera of Cordulidae represented in Indiana, one (Macromia) is cosmopolitan, one (Somatochlora) is circumpolar, and the remainder are Nearctic, mainly confined to eastern United States and Canada.

Didymops is a genus of two species. The non-regional species is known only from Florida.

The cosmopolitan genus Macromia contains about 80 nominal species, of which ten occur in the United States and Canada. The more or less compensating graphs of the several Indiana species, forming a somewhat even total band throughout the season for the genus as a whole, would seem to be of interest but there appears to be no explanation for it. Macromia and Didymops are rather distinctly separated from the other genera of the family found in Indiana, and are sometimes placed in a separate subfamily. The seasonal ranges of the species of Macromia are in marked contrast to those of the other Cordulidae, with the possible

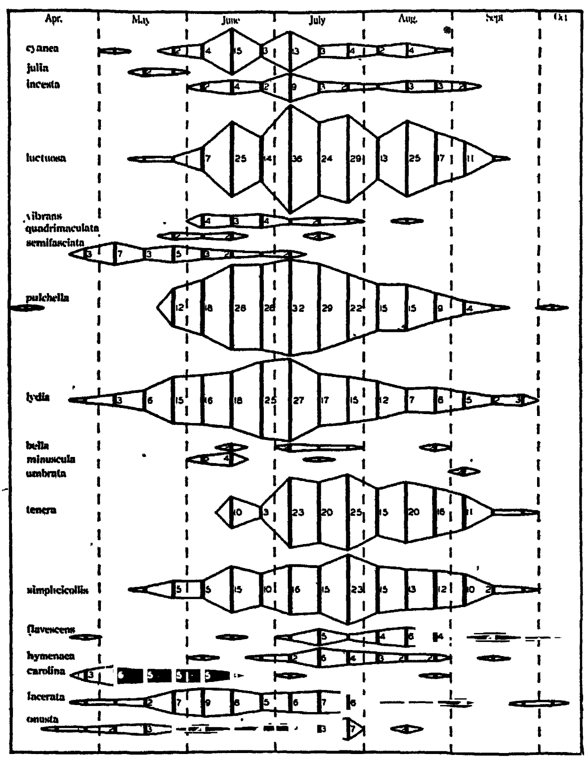

Fig. 2. The range of the flight season (or period of adult life) and the relative seasonal abundance of species of Libellulidae (genera Libellula, Nannothemis, Erythrodiplax, Perithemis, Erythemis, Pantala, and Tramea) in Indiana. Numbers near each bar indicate the number of collections of each species in each third of a month during the period of 1900 to 1940 inclusive; where no number is given the number of collections is one.

exception of *E. princeps*. This would seem to be in line with the more extensive range of the genus, although the individual species do not range over much greater areas than those of the other genera.

Epicordulia is a genus of two species and has a range almost duplicating that of Didymops, except that the non-Indiana species has a somewhat greater range through the Gulf states than that of *D. floridensis*. *E. princeps* is, by far, the most common cordulid in Indiana and is usually conspicuous, although not especially numerous, at any lake, gravil pit, or large pond throughout its season. Its abundance as compared with other species of the family is not adequately shown by the graphs. Species of Macromia and Somatochlora have been the objects of special search over the years, but *princeps*, a common species but very difficult to capture, has usually been disregarded in collecting.

Neurocordulia is a genus of four species which are found in the area from Louisiana and Missouri to the Atlantic coast. All of the species are quite rare.

Tetragoneuria is an American genus of 11 species and three subspecies or varieties, mostly eastern, although two are transcontinental, and one is probably confined to the central plains. Indiana appears to be at, or near, the southern limit of the range for two species, and all three Indiana species are spring and early summer forms. However, Indiana is near the the middle, or somewhat north of the middle, of the range of the third species, *cynosura*, and there are about as many southeastern as northeastern species in the genus.

Somatochlora is a large Holarctic genus, whose species range, for the most part, over territories of more northern latitude than Indiana. Walker (1925) recognized about 36 species—20 North American, 15 Eurasian, and one known from both hemispheres. Since 1925 three species have been described from each hemisphere. All of the species found in Indiana have been taken farther to the south, although some of their more southern range is in the mountains. Although *linearis* has been taken in August, and rather frequently in late July, the Indiana species may be called early season forms. One species, *hineana*, known only from the type series from Logan County, Ohio, has been included in the chart.

The distribution and the number of species (including subspecies) of each of the genera of Libellulidae represented in Indiana are given in the list below. The sequence is from primitive to specialized as indicated by Ris (1909-1918). While recognizing the limitations of a linear arrangement, Ris used this as the only practical method of showing evolutionary level, and divided the genera of Libellulidae into ten groups, although certain pairs of these were parallel Old and New World series. The Roman numerals in parenthesis following the subfamily names, indicating the groups, and the Arabic numerals before the generic names, indicating rank among the 120 libellulid genera, are indices of Ris' opinion of the relative evolutionary level of the several genera.

Libellulidae (II): 31.*Libellula*—33 species; Holarctic and Neotropical.

Palpopleurinae (III): 39.*Perithemis*—11 species; Neotropical (8) and Nearctic (4).

Brachydiplacinae (V): 51. *Nannothemis*—1 species; Nearctic.

Sympetrinae (VI): 65.*Erythrodiplax*—51 species; Neotropical (50). and Nearctic (5). 75.*Erythemis*—8 species; Neotropical (7) and Nearctic (2). 79.*Sympetrum*—about 60(?) species; chiefly Holarctic, but extending into bordering realms. 81.*Pachydiplax*—1 species; Nearctic.

Leucorrhiniinae (VII): 82.*Leucorrhinia*—17 species; Holarctic. 83: *Celithemis*—9 species; Nearctic and Cuba.

Trameinae (X): 108.*Pantala*—two species; cosmopolitan. 113.*Tramea*—11 species; cosmopolitan except Europe.

Although no close correlation between the seasonal range of the species in Indiana and their geographic range (or their evolutionary level) can be shown, certain tendencies and some individual cases of apparent correlation may be pointed out. Northern forms, for the most part, tend to occur, or to reach their maximum abundance, in Indiana, during the early season. More southern forms, those of wide range, or even more local species of genera with wide distribution, occur in mid-season, or have a long seasonal range. Any correlation between seasonal and geographic distribution is not causal inter se, but is due to a common effect of adaptiveness and activeness, both of which may have a close correlation with evolutionary level (Kennedy, 1928).

The evolutionary development of the species of Libellula has been studied by Kennedy (1922) who placed *semifasciata* as the most primitive, and *quadrimaculata* as the most specialized. *Semifasciata* has an early seasonal range in Indiana although the state is near the northern limit of its geogrphic distribution. *Quadrimaculata* also has a limited seasonal range in Indiana, but reaches its southern limit (outside of the mountains) here. *Julia* is very definitely northern in distribution and has a very short early seasonal range in Indiana.

The long seasonal ranges (although interrupted in some species) of the species of Pantala and Tramea is matched by the world wide distribution of these genera. *T. carolina,* evidently an early season form, in spite of two records in July and August, has the most limited geographic range of any species of these two genera.

The species of Sympetrum are the only late season forms among the Indiana representatives of the Libellulidae. Although Ris (1909-1918) placed this genus rather high in the evolutionary scale, Kennedy (1928) questioned this position. The genus is probably a complex group and may include several series of species of varying evolutionary development. Needham and Fisher (1936) have placed *corruptum* (and other species) in a separate genus, *Tarnetrum.* The pattern of the seasonal range of this species in Indiana is certainly different from that of the other species. It should be noted that *internum,* which was recorded from the state only once during the period of 1900 to 1940, was found to be abundant in Tippecanoe County in 1943 and 1944.

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A First List of Indiana Stoneflies (Plecoptera)[1]

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For about 20 years there has lived within a hundred miles of Indiana America's leading student of Plecoptera, Dr. T. H. Frison, of the Illinois Natural History Survey. Dr. Frison and his colleagues have not only collected stoneflies intensively in their home state, but have conducted numerous forays into adjacent territory and far afield. Naturally Indiana has been included in these expeditions, and many specimens from this state now rest in the INHS collection. To a considerable extent these records have not appeared in print, though it is to be hoped that a detailed list will be published. In some instances, however, particularly with new or rare species, Indiana locality records have appeared in Dr. Frison's papers.

More important than these actual published records, to a study of the Indiana stonefly fauna, has been the clarification of the status of the mid-western species in such difficult genera as *Acroneuria* and *Isoperla*. Without the numerous rearings of adults from nymphs which Dr. Frison has carried out, it would be an extremely difficult if not impossible task to separate the adults into specific groups, in these genera.

Though the writer has had an interest in Plecoptera for some years, he has not as yet found time to make systematic collections in Indiana. The new records given below are largely from two sources: the research and teaching collections at Purdue University, and the teaching collection at Indiana University. These provide a cross-section of most of the commoner and more conspicuous species in the state, while Dr. Frison's records add some of the rarities. In this way a list of 38 species has been assembled. This number will doubtless be substantially increased by future collecting, possibly by as much as half. The northeastern lake district, with its occasional spring streams, should be particularly searched for outlying population of a rich northern fauna; while along the Ohio River a number of southern species may creep into the state. Even in the central region new additions may be expected, particularly among the tiny species of the genus *Allocapnia.*

Of the species listed below, the only one which was entirely unanticipated, in the light of earlier work, is *Nemoura vallicularia.* Taken by casual collectors at both Lafayette and Bloomington, it can scarcely be uncommon in Indiana, but it is unknown in Illinois.

In what follows, specimens from Bloomington, and all those collected by the writer, are at Indiana University; those collected at Lafayette or in Tippecanoe County are from the Purdue Collection. For all others the collection is indicated as "IU" or "PU." In considering the dates on

[1] Contribution number 338 from the Department of Zoology, Indiana University.

which specimens were taken, it should be remembered that both at Bloomington and at Lafayette student collectors have been active principally from March to May. The classification for the most part follows that outlined in the writer's 1943 paper.

List of Species
Family Pteronarciidae

Pteronarcys pictetii Hagen, BLOOMINGTON. v.12.08, ♂; v.14.08, ♀, LAFAYETTE. v.7-11.14, ♀; iv.20.15, ♀; iv.21.25, ♂, J. J. Davis; iv.24.25, ♂; v.14.25, ♂; iv.30.28, ♂; also 22 ♂ 32 ♀, from iv.8 to viii.12, in various years. MORGAN Co. iv.25.31, ♂, Musgrave (PU). TIPPECANOE Co. v.3.38, ♂, G. E. Gould. TIPPECANOE RIVER STATE PARK—Tippecanoe river, exuviae, D. C. Scott.

Family Nemouridae
Subfamily Taeniopteryginae

Taeniopteryx maura Pictet, ALLEN Co. iii.30.41, ♀ (PU). BLOOMINGTON. iii.2-3.37, 2 ♀. ii.26.38, ♀, J. L. Stewart. CARROLL Co. iii.5.39, ♀ (PU). HAMILTON Co. v.3.36, ♀ (PU). JAY Co. iv.3.39, ♀ (PU). LAFAYETTE—chiefly or entirely from the Wabash river. 10 ♂ 54 ♀, i.19 to vi.1, in various years, but principally in March and April. LAKE WAWASEE—creek at SE end. iii.10.42, ♂, W. E. Ricker. MILL CREEK at Cataract falls, Owen Co. v.3.41, dead ♀, W. E. Ricker. NASHVILLE—Salt creek. iv.13.41, 4 ♀, W. E. Ricker. NEWTON Co. v.21.38, ♀ (PU). NORWAY—Tippecanoe river. iv.39, ♂ ♀, W. E. Ricker. VINCENNES—Wabash river. iii.9.41, 5 ♂ 4 ♀, C. H. Schockley (IU). WARSAW—Tippecanoe river. iii.9.41, ♂, W. E. Ricker. WINONA LAKE—Cherry creek. iii.9.41, 6 ♂ 4 ♀, W. E. Ricker.

Taeniopteryx lita Frison, ROGERS—White river. iii.14.36, 4 ♂ (Frison, 1942). ST. ANTHONY. ii.13.38, ♂ (Frison, 1942). WINSLOW—Patoka river. ii.14.38, 2 ♂ (Frison, 1942) .

Taeniopteryx fasciata (Burmeister), BASS LAKE—Hatchery outlet. iv.25.41, ♂, W. E. Ricker. BLOOMINGTON. iii.2.39, ♂. BENTON Co. v.9.39, ♀ (PU). CARROLL Co. iv.4.39, ♀ (PU). CASS Co. iii.29.40, ♂ (PU). LAFAYETTE—chiefly or wholly from Wabash river. 24 ♂ 29 ♀, ii.25 to v.21, in various years; chiefly late March and April. MORGAN Co. iv.2.29, ♂ (PU). NORWAY—Tippecanoe river. iv.39, ♂ ♀, W. E. Ricker. SEYMOUR. iii.20.34, ♀, R. Bugbee (IU). SPENCER. iv.39, ♂ (IU). VINCENNES. iii.9.41, 3 ♂ 1 ♀, C. H. Shockley (IU).

Subfamily Nemourinae

Neumoura vallicularia Wu, BLOOMINGTON. iii.26.22, ♀, A. C. Kinsey. ii.20.37, ♀. iii.7.37, ♀. LAFAYETTE. v.5.29, ♀. v.21.31, ♀, L. A. Schultz.

Nemoura venosa Banks, BLOOMINGTON. v.18.33, ♀, Pearson. MCCORMICKS CREEK STATE PARK. v.10.38, ♀, A. Hale (IU); iv.28.41, 19 ♂

7 ♀, W. E. Ricker. WINONA LAKE—creek 5 miles E. v.43, ♂♂ ♀♀, W. E. Ricker.

Subfamily Leuctrinae

Leuctra claasseni Frison, BLOOMINGTON. iii.29.38, ♂, J. L. Stewart. BLOOMINGTON—Griffy creek. v.18.40, ♂, W. E. Ricker. MARTINSVILLE—small creek S. iv.20.41, ♂ ♀, W. E. Ricker. MORGAN CO.—small creek. iv.20.41, ♂♂ ♀♀, W. E. Ricker. TURKEY RUN STATE PARK—Newby gulch. Nymph—Trib. of Sugar creek. iv.9.40, 11 ♂ 5 ♀, nymph (Frison, 1942).

Subfamily Capniinae

Allocapnia granulata (Claassen), LAFAYETE—Wabash river. iv.18.37, 2 ♀. WINONA LAKE—Cherry creek. iii.9.41, 148 ♂ 97 ♀, W. E. Ricker.

Allocapnia pygmaea (Burmeister), .BACON—creek SW. ii.14.38, 10 ♂ (Frison, 1942). MARENGO—creek E. ii.14.38, 2 ♂ (Frison, 1942). SPRINGVILLE. ii.14.38, 2 ♂ (Frison, 1942).

Allocapnia rickeri Frison, BACON—creek SW. ii.14.38 ♂♂ ♀♀, —Patoka river. ii.14.38, ♂♂ ♀♀ (Frison, 1942). BLOOMINGTON. iv.5.37, ♀, Denham. ENGLISH—creek N. ii.14.38, ♂♂ ♀♀ (Frison, 1942). MCCORMICKS CREEK STATE PARK. iii.14.36, ♂♂ ♀♀ (Frison, 1942) MCCORMICK'S CREEK STATE PARK—McC. creek. iv.12.41, 5 ♂ 14 ♀; iv.2.42, ♂ 9 ♀; W. E. Ricker. MARENGO—creek W. ii.14.38, ♂♂ 2 ♀ (Frison, 1942). MEDORA—Creek NW. ii.14.38, 2 ♂ (Frison, 1942). MILLTOWN—creek W. ii.14.38, 8 ♂ 1 ♀ (Frison, 1942). NEEDMORE—creek. iii.14.36, ♂♂ ♀♀ (Frison, 1942). PALMYRA—Blue river. ii.14.38, ♂♂ ♀♀ (Frison, 1942). PAOLI—S. ii.14.38, ♂♂ ♀♀ (Frison, 1942). SALEM—river S. ii.14.38, 6 ♂ 4 ♀ (Frison, 1942). SPRINGVILLE. ii.14.38, ♂♂ ♀♀ (Frison, 1942). TURKEY RUN STATE PARK. iii.18.33, ♀.—Sugar creek. iv.19.33, 2 ♀ (Frison, 1942). WILLOW VALLEY. iii.14.36, ♂♂ 1 ♀ (Frison, 1942).

Allocapnia vivipara (Claassen), ADAMS CO. iv.1938, ♀ (PU)., BLOOMINGTON. iv.17.37, 2 ♀, Nestman. OWEN CO.—Mill creek at Cataract falls. v.3.41, dead ♂, W. E. Ricker.

Nemocapnia carolina Banks, ROGERS—White river. iv.16-21.36, ♂ ♀; iv.14-17.40, 3 ♀ (Frison, 1942). SHOALS—White river. iv.5.40, ♀ (Frison, 1942).

Family Perlidae

Subfamily Perlinae

Neophasganophora capitata (Pictet), LAFAYETTE. v.11.41, ♂. OWEN CO.—Mill creek at Cataract falls. v.3.41, exuvia, W. E. Ricker.

Togoperla kansensis (Banks), BLOOMINGTON. ix.27.39, ♀. LAFAYETTE. vi.14.44, ♀. WHITE RIVER (probably near Petersburg). "In numbers" (Frison, 1937).

Subfamily Neoperlinae

Neoperla clymene (Newman), BEDFORD. vii.6.28, ♀, L. F. Steiner (PU). BLOOMFIELD. vii.22.39, ♀, Bates (IU). BLOOMINGTON. vii.2.38, ♀, Hancock. vii.1.40, ♀, Thompson. vii.30.40, ♀. viii.10.42, ♀. CLARK CO. STATE FOREST. vi.26.38, ♂, Brackman (PU). LAFAYETTE. vii.29.22, ♀, G. M. Stirrett. vii.2.23, ♀. TIPPECANOE CO. vi.20.39, ♀. VINCENNES. vi.17.32, ♂ (PU). vi.28.30, 2 ♀, E. M. Becton (Canadian National Collection). WARREN CO. vi.30.35, ♂, D. W. LaHue (PU).

Subfamily Acroneuriinae

Acroneuria abnormis (Newman), BLOOMINGTON. v.30.37, ♂. LAFAYETTE. v.19.30, ♂; v.10.41, ♂; v.21.41, ♀; v.25.41, ♂; ix. 16.41, ♀; vii.5.42, ♀; ix.17.42, ♀; vi.14.44, ♀. TIPPECANOE CO. vi.7.39, ♂ ♀; vi.16.39, ♂, D. W. LaHue; vii.2.39, ♀. TIPPECANOE RIVER STATE PARK—Tippecanoe river, vi.15.44, ♂; vi.20.44, ♀; D. C. Scott (IU).

Acroneuria evoluta Klapálek, BLOOMINGTON. v.1922, ♂; v.21.38, ♂ ♀; vi.29.40, 2 ♀; vi.18-19.42, 2 ♂. CLARK CO. STATE FOREST. vi.15.38, ♂ ♀ (PU). HARRISON CO. vi.20.34, ♂, D. W. LaHue (PU). LAFAYETTE. iv.28.25, ♀; vi.14.44, ♂ (PU). MCCORMICK'S CREEK STATE PARK. v.10.38, ♂ ♀, A. Hale (IU). OWEN CO. v.30.36, ♀, Deay & Gould (PU). WINONA LAKE. vi.20.42, ♂, W. E. Ricker.

Acroneuria internata (Walker), HARRISON CO. vii.1.34, ♀, D. W. La Hue (PU). LAFAYETTE. vii.11.36, ♂; iv.14.42, ♂.

Acroneuria mela Frison, BLOOMINGTON. vi.29.43, ♀, Best. CLARK CO. STATE FOREST. vii.6.35, ♀ (PU). EVANSVILLE. v.26.21, ♂ (PU). LAFAYETTE. v.6.30, ♂. PETERSBURG—White river. vi.3-vii.6.36, 5 ♂ 19 ♀ reared from nymphs (Frison, 1942; also as *A. evoluta*, Frison, 1937).

Acroneuria perplexa Frison, BLOOMINGTON. vi.20-29.39, 2 ♀, Rellinger; vi.23.40, ♀; vi.10.43, ♂, W. Coggeshall; vi.24.43, ♀, Best. CLARK CO. STATE FOREST. vii.36, ♀ (PU). EVANSVILLE. v.26.21, ♂ (PU). LAWRENCE CO. iv.31.33, ♀, Musgrave (PU). PETERSBURG—White river. vi.4-24.36, 2 ♂, 5 ♀, nymphs (Frison, 1937). PORTERSVILLE—White river, nymphs (Frison, 1937). ROGERS—White river. v.26.27, 3 ♀, nymphs (Frison, 1937) TIPPECANOE CO. vi.19.37, ♂. VINCENNES. vi.22.31, ♀ (PU). vi.28.30, ♀, E. M. Becton (Canadian National Collection)

Acroneuria ruralis (Hagen), BLOOMINGTON. vi.18.44, ♂, S. Lockett. LAFAYETTE. vi.14.44, ♀. An unlabelled ♂ probably belongs here. TIPPECANOE CO. vi.16.39, ♀, D. W. LaHue.

Atoperla ephyre (Newman), BLOOMINGTON. v.14.08, ♂ ♀.

Perlesta placida (Hagen), BEDFORD. vii.6.28, 2 ♂ 1 ♀, L. F. Steiner (PU). BLOOMINGTON. v.26.38, 2 ♀, Hall, Minton; vii.9.38, ♀, Sherrill; vi.18.39, ♀, Davis; vii.24.40, ♂; viii.2.40, ♂; vi.6.44, ♂, E. Naugle. CLARK CO. STATE FOREST. vii.5.33, ♂; vi.5-19.37, ♂ 2 ♀; vi.10.40, 2 ♀;

(PU). FORT WAYNE. vi.17.21, ♂ (PU). GREENE Co. vii.11.01, ♂ (PU). HENRYVILLE. vi.14.32, ♀ (PU). KOSCIUSKO Co. vi.17.33, ♀, G. E. Gould (PU). LAFAYETTE. vi.17.32, ♂; v.24.40, ♂; v.20-24.41, ♂ 2 ♀; vi.20.42, ♀; vii.8.43, ♂ ♀. MORGAN Co. vi.28.32, ♀; vi.18.33, ♀; Musgrave (PU). POSEY Co. vi.16.33, ♀, B. E. Montgomery (PU). SPENCER—White river. vi.5.44, 2 ♂ 1 ♀, 8 nymphs, W. E. Ricker. TIPPECANOE Co. vi.16-20.39, 2 ♂ 3 ♀, G. E. Gould & D. W. LaHue. WARSAW. vi.26.24, ♀, K. M. Richter (IU). WINONA LAKE. Summer, 1926, ♀; viii.17.34, ♂, R. J. Kulasavage (IU). WINONA LAKE—Cherry creek. vi.21.42, ♀, W. E. Ricker.

Perlinella drymo (Newman), BLOOMINGTON. v.08, ♀. v.6.39, ♀, W. E. Ricker. TURKEY RUN STATE PARK. v.7.22, ♀ (IU).

Family Perlodidae

Subfamily Isogeninae

Diploperla duplicata (Banks), TURKEY RUN STATE PARK—Newby gulch. v.11-12, adults reared from nymphs (*Isoperla duplicata*, Frison, 1935).

Hydroperla crosbyi (Needham & Claassen), GOSPORT—White river. iv.9.34, ♀, R. Bugbee (IU). LAFAYETTE. v.3.38, ♂. MORGAN Co. vi.10.33, ♀, Musgrave (PU).

Hydroperla harti Frison, LAFAYETTE. iv.25.36, ♀; v.10.37, ♀ (PU).

Hydroperla varians (Walsh), LAFAYETTE. iv.30.29, ♂; v.10.33, ♀; v.31.33, ♀; v.11.39, ♀; v.14.39, ♀; v.18.40, ♀. PETERSBURG—White river. Exuviae (Frison, 1937). PORTERSVILLE—East Fork White river. Exuviae (Frison, 1937). ROGERS—White river. ♂ ♀ from nymphs, exuviae (Frison, 1937).

Subfamily Isoperlinae

Isoperla bilineata (Say), BLOOMINGTON. 34 ♂ 20 ♀, from iv.11 to v.21, in various years. Also, ii.18.38, 2 ♂ 1 ♀; vi.21.38, ♀. The February occurrence is unexpected, but perhaps not impossible. CLARK Co. STATE FOREST. vii.2-20.38, 2 ♂ (PU). GOSPORT. iv.17.38, ♀, R. Bugbee (IU). LAFAYETTE. 28 ♂ 10 ♀, iv.26 to v.26, in various years. NEW ALBANY. iv.17.38, ♀, Minton (IU). WASHINGTON Co. v.7.36, ♀ (PU).

Isoperla burski Frison, BLOOMINGTON. iv.30.33, ♀, H. Rainwater.

Isoperla confusa Frison, BLOOMINGTON. iv.9.21, ♀. iv.20.22, ♀, A. C. Kinsey. LAFAYETTE. vi.41, ♀. MONTEZUMA. iv.13.33, ♂—Leatherwood creek, nymphs (Frison, 1935). THE SHADES. Nymphs (Frison, 1935). TURKEY RUN STATE PARK—Sugar creek. iv.19.33, ♂; v.7.33, ♀; nymphs. Newby gulch. v.11.33, ♀, nymphs (Frison, 1935). VEEDERSBURG—Coal creek. Nymphs (Frison, 1935). WARREN Co. iv.23.33, ♀, G. E. Gould (PU).

Isoperla decepta Frison, BLOOMINGTON. v.28.37, 2 ♀. v.3.38, ♀, Tinsley. v.16.41, ♀, Pitman. LAFAYETTE. v.12.39, ♂.

Isoperla dicala Frison, KNOX—Yellow river. v.24.37, ♂ (Frison, 1942).

Isoperla marlynia Needham and Claassen, ROGERS—White river. iv.19.36, ♀ reared; iv.24.36, ♀; iv.10-21.40, 2 ♂ 2 ♀ reared (Frison, 1942).

Isoperla minuta Banks, LAFAYETTE. v.11.41, ♀. TIPPECANOE CO. vi.2.33, ♂ ♀, Musgrave. WARSAW—Tippecanoe river. v.27.43, ♂ ♀, D. C. Scott (IU).

Isoperla namata Frison, BLOOMINGTON. v.19.08, ♀. MCCORMICK'S CREEK STATE PARK. iv.16-23.38, 3 ♂ 1 ♀, from nymphs (Frison, 1942). iv.28.41, 2 ♂, W. E. Ricker.

Isoperla truncata Frison, KNOX—Yellow river. v.24.37, 21 ♂ 4 ♀ (Frison, 1937).

Family Chloroperlidae

Subfamily Chloroperlinae

Hastaperla brevis (Banks), TURKEY RUN STATE PARK. v.30.30, ♀; v.22.32, ♀. Newby gulch. v.11-12.33, ♂♂ ♀♀, also nymphs.—Sugar creek. Nymphs (Frison, 1942; also mentioned as *Chloroperla cydippe*, Frison, 1935).

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INDEX

Abbott, R. B., 193.
Acids, Inhibited, for recovering tin from tin cans, 112.
Adams, W. B., 25.
Adams, W. R., 25.
American Indians, 41.
Angel Mounds Site, botanical survey of, 49.
Anthropology, Section on, 25.
Antibiotic substances from plants, 52.
Atmosphere, new explanation of the circulation, 124.
Bacteria, "nibbled" colonies resistant to viruses, 51.
Bacteria, non-toxic strains of, 52.
Bacteriology abstracts, 51.
Bacteriology, Section on, 51.
Baechle, (Rev.) John W., 201.
Behavior development, ability of pupils to recognize principles of, 194.
Billman, John H., 101.
Bird-Banding activities from April, 1941, to November, 1944, A Summary of, 201.
Birds of Indiana, 200.
Bog formation and lake filling, 79.
Botanical survey of the Angel Mounds Site, 49.
Botany abstracts, 79.
Botany, Section on, 79.
Breneman, W. R., 207.
Cable, R. M., 197.
Calumet region, toponomy of, 142.
Cans, recovery of tin from, 112.
Cellulose decomposition, thermophilic, 75.
Chemistry abstracts, 100.
Chemistry, Section on, 100.
Chicks, response of, to pituitary gonadtropins and pregnant mare serum, 207.
Clostridium tetani, non-toxic strains of, 52.
Clostridium welchii, 54.
Committees for 1944, v.
Cordulidae—Indiana species, 217.
Deam, Charles C., 91.
Degering, Ed. F., 114.
Determination of non-aminoid nitrogen, 117.
Detinning scrap tin with inhibited acids, 112.
Dimethylamine, vapor pressure of, 121.
Divisional chairmen, 1943, v; 1944, xiii
Dragonfly, common names, 161; poetical references, 161; study in Indi ana, 161.
Editor and publication of Proceedings, ix.
e in elementary calculus, 184.
Elijah Swift, Jr., 121.
Entomologists Meeting, xiv.
Ethers of starch, 114.
Evans, Arthur Thompson, 1.
Executive Committee, Minutes, viii.
Explosions, gas mixtures for rapid, 193.
Fighting in mice, effects of spatial restriction on, 199.
Floods, causes in Indiana, 134.
Floods, damage, methods of reduction, 134.
Flood frequencies in Indiana, 134.
Floods in Indiana, 134.
Florida, Pleistocene of Palm Beach County, 125.
Fox, action of morphine on, 214.
Fraxinus, epidermal characters in, 84.
Friesner, Ray C., 91.
Fructose, in white potatoes, 100.
Functions, elementary, 144.
Fungi, utilization of staled media by, 81.
Gangrene, gas, 54.
Gantz, E. St. Clair, 105.
Gas gangrene, 54.
Gas mixtures for rapid explosions, 193.
General Session, Minutes, xiii.
Geographic education, 124.
Geography class grades, 130.
Geography and Geology in the curriculums of Colleges and Universities of Indiana, 125.
Geology and Geography, abstracts, 124.
Geology and Geography, Section on, 124.
Gertrude Marie, Sister, 185.
Girton, Raymond E., 79.
Glycerine foots, inhibiter for reducing the action of acids on iron, 112.
Gonads, development of, 199.
Goniobasis species, 197.
Graham, Frank Vern, 2.
Gray, William D., 79.
Growing season, Vigo County, Indiana, 126.
Harmonic analysis of voice quality, 194.
Headlee, William Hugh, 198.
Hochandel, Helen Phillips, 121.
Herman, David T., 194.
Hiestand, William A., 198, 214.
Hildebrand, Carroll D. W., 160.
Hill, Harris, 196.
Historian views science, 160.

Historic floods in Indiana, 134.
History of Science, Abstracts, 160.
History of Science in Indiana, preparation of proposed, 179.
History of Science, Section on, 160.
Householder, J. C., 29.
Hypoxic resistance in mice, 198.
Indian corn, early history, 169.
Indiana, birds, 200.
Indiana, first list of stoneflies of, 225.
Indiana floods, 134.
Indiana, growing season in Vigo County, 126.
Indiana karst 8.
Indiana, parasites of man in, 198.
Indiana, plant distribution, 91.
Indiana, record 30-day rainfalls, 134.
Inhibited acids, for recovering tin from tin cans, 112.
Jonah, H. F. S., 184.
Just, Theodor, 160.
Karst, Indiana, 8.
Kaslow, C. E., 107.
Keeler, M. W., 184.
Koch, G. David, 126.
Lake filling and bog formation, 79.
Lake forest, 80.
Lead, qualitative detection in the presence of bismuth, copper and cadmium, 105.
Lenape, tentative speculations on the migration route of the, 33.
Levees in Indiana, 134.
Libellulidae, Indiana species, 218.
Library committee, report of, x.
Lieber, Richard, 3.
Lilly, Eli, 33.
Long, Alma, 194.
Lott, A. V., 124.
Lundin, R. W., 195.
Luria, S. E., 51.
McClure, S. M., 130.
McLung, L. S., 52.
Marion County, Oliver Farm Site, 29.
Mathmematics abstracts, 184.
Mathematics classics in college teaching, 185.
Mathematics, final grades in freshman, 184.
Mathematics, Section on, 184.
Mathers, F. C., 112.
Mayer, Brantz, 44.
Menger, Karl, 184.
Meyer, Alfred H., 124, 142.
Mice, defensive fighting of male, 199.
Mice, effects of spatial restriction on defensive fighting of, 199.
Middleton, Arthur Renwick, 4.
Migrations, American Indian, 41.
Miller, Helen Rogers, 198.
Minutes of Executive Committee, viii.
Minutes of General Session, xiii.
Monroe County, archeological survey, 25.
Montgomery, B. Elwood, 161, 217.
Morphine, action on red fox, 214.
Morphophyles, human, 41.
Moulton, Benjamin, 125.
Music tests, new, 195.
Myxomycete physarum polycephalum Schw., physiological strains of, 79.
Necrology, 1.
Neuman, Georg, 41.
New members, xv.
Nitrogen, determination of non-aminoid, 117.
Nitrogen oxides in ozonized air, 107.
Odonata—distribution of Indiana species, 217.
Odonata, history of study in Indiana, 161.
Officers for 1944, v; 1945, xiii.
Ohio River floods, 134.
Oliver Farm Site, 29.
Ozonized air, oxides of nitrogen in, 107.
Palm Beach County Florda, Pleistocene of, 125.
Parasites of man in Indiana, 198.
Pepper, Paul M., 184.
Perseveration in normal speakers and stutterers, 196.
Pharmacological action of morphine on red fox, 214.
Physical types, American Indian, 41.
Physics, Abstract, 193.
Physics, Section on, 193.
Pi in elementary calculus, 184.
Pituitary gonodotropins, response of chicks to, 207.
Plant distribution, Indiana, 91.
Plants, antibiotic substances from, 52.
Plecoptera of Indiana, 225.
Pleistocene of Palm Beach County, Florida, 125.
Polyanhydrides, reaction with thiophene, 101.
Polyploids, size of stomata in, 84.
Porter, C. L., 81.
Potzer, J. E., 79, 80.
Powell, H. M., 66.
Pratt, D. B., 75.
Pregnant mare serum, response of chicks to, 207.
Presidential address, 8.
Psychology Abstracts, 194.
Psychology, Section on, 194.
Rafinesque, S. C., 44.
Rankin, David, 114.
Rat, development of gonads of, 199.
Recursion inequalities, 184.
Respiration of maize roots, 79.

Rettger, Louis John, 6.
Ricker, W. E., 225.
Sanders, Dorothy, 52.
Say, Thomas, 162.
Science, critique of, 160.
Science, historian views, 160.
Science, History of, in Indiana, preparation of proposed, 179.
Science, men of, in Indiana, past and present, 179.
Scott, J. P., 199.
Sears, Louis M., 160.
Seitner, Philip G., 197.
Sequent occupance in Calumet area, 142.
Smith, Ernest Rice, 125.
Smith, George Hume, 7.
Somers, P. D., Jr., 117.
Spring Meeting 1944, xiv.
Staled media, utilization by fungi, 81.
Starch, ethers of, 114.
Stayner, E. Dale, 107.
St. Joseph's College, a summary of bird-banding activities from April, 1941 to November, 1944, 201.
Stomata, use in identification, 84.
Stoneflies of Indiana, 225.
Stullken, Donald E., 214.
Stutterers, perseveration in, 196.
Table of contents, iii.
Taxonomists Meeting, xiv.
Thiophene, reaction with polyanhydrides, 101.
Thrun, W. E., 100.
Tin, recovery from tin cans, 112.
Tippecanoe river, trematode parasites from, 197.
Toabe, Ruth, 52.
Toponomy, Calumet region, 142.
Torrey, Theodore W., 199.
Travis, Frank H., 101.
Treasurers report, viii.
Trematode parasites from Tippecanoe river, 197.
Trial-balance sheet for root respiration, 79.
Trustee, report of Academy, viii.
Type concept in modern biology, 160.
Vaccine for influenza virus, 66.
Vapor pressure of dimethylamine, 121.
Vigo County, growing season, 126.
Viruses, bacteria resistant to, 51.
Viruses, interference between closely related, 51.
Visher, Stephen S., 134.
Vogel, Howard H., Jr., 200.
Voice quality, harmonic analysis of, 194.
Vowels, 194.
Vulpes fulva, action of morphine on, 214.
Wabash River Floods, 134.
Walam Olum manuscript, 44.
Walam Olum, tentative speculations on the chronology of the, 33.
Weatherwax, Paul, 169.
Weatherwax, Paul W., 52.
Weed, Lyle A., 54.
Weer, Paul, 44.
Weith, R. J., 164.
White River floods, 134.
White River, Oliver Farm Site, 29.
Williamson, E. B., 162, 163.
Wilson, Ira T., 79.
Winter Meeting, 1944, program, vii.
Woodland culture, 41.
Wright, John S., 179.
Wright, Jonathan W., 84.
Xiphidiocercaria of virgula type, 197.
Zeiner, Helen Marsh, 49.
Zoology Abstracts, 197.
Zoology, Section on, 197.

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October 18, 19 and 20, 1945

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Reprints of certain parts of recent volumes of the Proceedings are available for distribution as follows: copies of the constitution and by-laws (Vol. 44), and complete membership list (Vol. 50), may be secured by members elected subsequent to the publication of those volumes; copies of the codified list of duties of officers (Vol. 48) may be secured by officers, divisional chairmen, and chairmen of committees; and copies of the necrology can be supplied to relatives and friends of the deceased members. Inquiries concerning these reprints should be addressed to the Secretary of the Academy, Dr. Winona H. Welch, DePauw University, Greencastle, Indiana.

Reprints of technical papers in recent volumes can often be secured from the authors. They cannot be supplied by the State Library nor by the officers of the Academy.

Application blanks for membership are available from members of the Membership Committee or from the Secretary.

Excerpts from the Constitution of the Indiana Academy of Science

Article I.

Sec. 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science. The Academy shall promote intercourse between men engaged in scientific work, especially in Indiana, assist by investigation and discussion in developing and making known the educational, material and other resources and riches of the state, prepare for publication such reports of investigation and discussion as may further the aims and objects of the Academy as set forth in these articles.

Article II.

Sec. 2. Any person interested in any department of scientific work shall be eligible to membership. They shall pay an admission fee of one dollar and one dollar dues and thereafter an annual fee of one dollar.

Sec. 4. The Indiana Academy of Science shall actively promote the organization and operation of local science clubs in connection with secondary schools of the state. Such of these clubs as elect to become members shall constitute the Indiana Junior Academy of Science.

TABLE OF CONTENTS

	Page
Officers and Committees for 1945	v
Program of the Winter Meeting	vii
Minutes of the Executive Committee	viii
Minutes of the General Session	xiii
New Members	xv
Indiana Junior Academy of Science	xviii
Member Clubs Indiana Junior Academy of Science	xxiii
Necrology	1
Presidential Address—MILLARD S. MARKLE	8

Anthropology

Abstract of paper not published in full	15
W. R. ADAMS: A Preliminary Report on Martin County	16
G. A. BLACK: The Cato Site—Pike County, Indiana	18
J. C. HOUSEHOLDER: Virginia's Indian Neighbors in 1712	23
GEORG NEUMANN: On the Physical Types of the Shoshonean-Speaking Tribes	26
PAUL WEER: Passamaquoddy and Quapaw Mnemonic Records	29

Bacteriology

Abstracts of papers not published in full	33
F. J. MURRAY: An Agar Decomposing Organism Isolated from Soil	34

Botany

Abstracts of papers not published in full	36
R. E. GIRTON: Some Concepts of the Respiration of Seed Plants	39
A. T. GUARD: An Abnormal Fruit Character in Tomato	46
F. A. LOEW: Observations of the Growth of an Injured Plant of Dirca Palustris	48
Indiana Plant Distribution Records, VI. 1945	50

Chemistry

WILLIAM A. ALLEN with ED. F. DEGERING: Synthesis and Reactions of Ketenes	65
J. W. MENCH with ED. F. DEGERING: The Nitrogen Dioxide Oxidation of Starch	69

Geology and Geography

Abstract of paper not published in full	77
MUZAFFER ERSELCUK: Iron and Steel Industries of Manchuria	78
O. W. FREEMAN: Geologic Contrasts in Indiana State Parks	83
G. D. KOCH: Needed, More Secondary School Geography	89
R. G. LILLARD: Some Factors Which Enabled Europeans Successfully to Settle the American Forests	92
C. A. MALOTT: The Buddha Outlier of the Mansfield Sandstone, Lawrence County, Indiana	96
R. R. SHROCK: Calcitic Pisolites Forming in Travertine Cascade Deposits	102

Page

R. R. SHROCK: Surficial Breccias Produced from Chemical Weathering of Eocene Limestone in Haiti, West Indies .. 107

R. R. SHROCK: Karst Features in Maya Region of Yucatan Peninsula, Mexico 111

R. R. SHROCK: Sedimentation and Wind Action Around Volcan Paricutin, Mexico 117

E. R. SMITH: Sand 121

S. S. VISHER: When the Seasons Begin in Indiana 144

History of Science

THEODOR JUST: A Brief History of the Department of Biology, University of Notre Dame 147

H. E. ZABEL and STEPHEN S. VISHER: Living Indiana Scientists, A Statistical Study 154

Mathematics

Abstracts of Papers not published in full 163

Physics

Abstracts of papers not published in full 164

R. R. RAMSEY: Radiation from an Electron Using the Formula, H = Curl Idl/r 168

Psychology

Abstracts of papers not published in full 170

JAMES DEESE and W. N. KELLOGG: Modification of Reflex Behavior in Spinal Dogs 171

G. R. STONE: Retention of Nonsense Syllables over Short Intervals of Time 178

Zoology

Abstracts of papers not published in full 182

K. K. LIAPTCHEFF and W. R. BRENEMAN: Demonstration of Urinary Gonadotropins in Normal Men, Using the Chick as a Test Animal 185

C. L. ROSE, J. R. HANNAH, and K. K. CHEN: Cellular Constituents and Chemistry of the Hamster's Blood 190

D. C. SCOTT: Notes on the Odonata of the Tippecanoe River State Park, Pulaski County, Indiana 196

T. W. TORREY: Phylogenetic Interpretations in the Teaching of Comparative Vertebrate Anatomy 206

OFFICERS AND COMMITTEES FOR 1945

OFFICERS

President, M. S. MARKLE, Earlham College.

Vice-President, J. F. MACKELL, Indiana State Teachers College.

Secretary, WINONA H. WELCH, DePauw University.

Treasurer, W. P. MORGAN, Indiana Central College.

Editor, R. C. CORLEY, Purdue University.

Press Secretary, C. M. PALMER, Butler University.

Trustees of Academy Foundation: J. S. WRIGHT, Eli Lilly & Company (term expires 1948), chairman; F. B. Wade, Shortridge High School (term expires 1947).

Committee for Bonding of Trustees: R. C. FRIESNER, Butler University chairman; Scott McCoy, Indianapolis.

Research Grant Committee: T. G. YUNCKER, DePauw University (term expires 1949) chairman; H. E. ENDERS, Purdue University, (term expires 1945); A. L. FOLEY, Indiana University, (deceased 2-13-1945), (term expires 1946); E. G. MAHIN, University of Notre Dame, (term expires 1947); J. S. WRIGHT, Indianapolis, (term expires 1948); M. S. MARKLE, Earlham College, (ex officio); Winona H. Welch, DePauw University, (ex officio).

DIVISIONAL CHAIRMEN

Anthropology, J. C. HOUSEHOLDER, Indianapolis.
Bacteriology, C. M. PALMER, Butler University.
Botany, R. E. GIRTON, Purdue University.
Chemistry, C. W. HOLL, Manchester College.
Geology and Geography, E. R. SMITH, DePauw University.
History of Science, JOHN S. WRIGHT, Indianapolis.
Mathematics, JUNA L. BEAL, Butler University.
Physics, R. E. MARTIN, Hanover College.
Psychology, W. N. KELLOGG, Indiana University.
Zoology, W. R. BRENEMAN, Indiana University.

EXECUTIVE COMMITTEE

(Past Presidents, Officers, Divisional Chairmen, and Chairmen of Standing Committees)

Juna L. Beal, C. A. Behrens, W. R. Breneman, S. Burrage, O. B. Christy, W. A. Cogshall, R. C. Corley, E. R. Cumings, J. J. Davis, C. C. Deam, W. E. Edington, H. E. Enders, R. C. Friesner, W. G. Gingery, R. E. Girton, C. W. Holl, J. C. Householder, Theodor Just, W. N. Kellogg,

Eli Lilly, J. F. Mackell, E. G. Mahin, C. A. Malott, M. S. Markle, E. S. Martin, R. E. Martin, M. G. Mellon, W. P. Morgan, C. M. Palmer, F. Payne, J. E. Potzger, R. R. Ramsey, W. E. Ricker, E. R. Smith, J. E. Switzer, F. B. Wade, F. N. Wallace, Paul Weatherwax, Winona H. Welch, J. S. Wright, T. G. Yuncker, H. L. Bruner (deceased 3-17-1945).

BUDGET COMMITTEE

(President, Secretary, Teasurer, Editor, and Chairmen of Committee on Relation of Academy to State, Program Committee, and Library Committee)

M. S. Markle, R. C. Corley, W. G. Gingery, W. P. Morgan, J. E. Potzger, F. N. Wallace, Winona H. Welch.

STANDING COMMITTEES

(Appointed by the President, Chairman of each committee named first)

Auditing: E. S. Martin, K. S. Means.

Biological Survey: W. E. Ricker, R. M. Kriebel, W. P. Allyn, H. O. Deay, H. H. Michaud,. B. E. Montgomery, C. M. Palmer, Dorothy Parker, Winona H. Welch.

Invitations: C. M. Palmer, A. R. Bechtel, Edward Kintner, Fred Loew, S. S. Visher.

Junior Academy of Science: H. E. Enders, W. P. Allyn, O. B. Christy, F. R. Elliott, M. S. Markle, C. L. Porter, F. B. Wade, M. M. Williams, T. G. Yuncker.

Library: W. G. Gingery, Nellie M. Coats, R. C. Friesner.

Membership: J. E. Switzer, G. F. Hennion, W. E. Martin, J. E. Potzger.

Nominations: H. E. Enders, F. Payne, T. G. Yuncker.

Program: J. E. Potzger, Juna L. Beal, May Iske, Charles C. Josey.

Publication of Proceedings: R. C. Corley, P. D. Edwards, Paul Weatherwax.

Relation of Academy to State: F. N. Wallace, E. Y. Guernsey, Eli Lilly, H. J. Reed, J. S. Wright.

Representative on Council of A.A.A.S.: H. E. Enders.

Resolutions: O. B. Christy, Theodor Just, Naomi Mullendore.

SPECIAL COMMITTEE

Fifty Year Index: Ray C. Friesner, Nellie M. Coats, W. P. Morgan, F. N. Wallace, Paul Weatherwax.

PROGRAM OF THE WINTER MEETING

BUTLER UNIVERSITY

October 18-20, 1945

THURSDAY, OCTOBER 18

7:30 P. M.

Meeting of the Executive Committee

FRIDAY, OCTOBER 19

9:30 A. M. General Session

Address of Welcome. Dr. C. R. Maxam, Registrar, Butler University.

Response. President Millard S. Markle.

Necrology W. E Edington, DePauw University.

Indiana Scientists Sketched in American Men of Science. H. E. Zabel and Stephen S. Visher, Chicago, Illinois, and Indiana University.

Sand. Ernest Rice Smith, DePauw University.

EXHIBIT—

1. Miss Nellie Coats, New materials in the Academy Library

11:45 A. M. and 2:30 P. M. Sectional Meetings

6:30 P. M. Annual Dinner

Business Session.

President's Address. "Biology and the Postwar World." President Millard S. Markle, Earlham College.

SATURDAY, OCTOBER 20

9:00 A. M.

Taxonomists Meeting

Entomologists Meeting

Junior Academy of Science

MINUTES OF THE EXECUTIVE COMMITTEE

INDIANAPOLIS, October 18, 1945

The Executive Committee was called to order by President Markle at 7:50 p.m., in Lincoln Room, Hotel Lincoln. Approximately forty members were in attendance. The reports of officers and committee representatives were presented and accepted as follows:

Academy Trustee. Report of John S. Wright, Frank B. Wade, and W. P. Morgan, Trustees of the Foundation Fund, Indiana Academy of Science, for the year 1944-1945.

Balance from the previous year	$	73.76
Total receipts		171.55
Bonds called		100.00
Total	$	345.31
Expenditures—Union Trust Co. Fee 5% on $253.68		12.69
Cash balance at Union Trust Company	$	332.62

Assets in the Fund as of October 28, 1945

Five $1,000 U. S. Savings Bonds Series "D", Cost	$ 3,750.00
$6,400 U. S. Treasury Series "G" Bonds, Cost	6,400.00
Six shares Standard Oil of Indiana Common Stock, par	150.00
Total at par or cost	$10,300.00

Auditing Committee. E. S. Martin stated that the accounts of the Academy Trustees and the Treasurer have been carefully checked and found in good order.

Treasurer. W. P. Morgan presented a tentative financial report for the period from January 1 to October 1, 1945. His final report, approved by the Auditing Committee at the end of the year follows:

Receipts

Balance on hand January 1, 1945	$1,814.54	
Dues and initiation fees	882.00	
Research grant refunded by administrator of Dr. Foley's estate	75.00	
Author's reprints, Vol. No. 51	20.56	
Author's reprints, Vol. No. 52	8.25	
Author's reprints, Vol. No. 53	144.75	
Gift memorial to Dr. H. L. Bruner	25.00	
Designated gift	500.00	
Publications sold by Librarian	6.00	
		$3,476.10

Disbursements

1—Program Committee	$ 124.27		
2—Editor	200.00		
3—Expenses of Secretary	45.96		
4—Expenses of Treasurer	71.00		
5—Mailing Proceedings	34.88		
6—Stationery	42.41		
7—*Preparation of fifty-year index	70.00		
8—Surety Bond	25.00		
9—*Preparation "Indiana Men of Science"	3.50		
10—*Foundation Fund	25.00		
11—Research grant, J. A. Potzger	25.00		
12—Research grant, Kenneth Wagner	50.00		
13—Postage refund, R. E. Girton	2.70		
14—Returned checks	9.00		
15—Cost of reprints, Vol. No. 54	403.90		
		$1,132.62	
†Balance on hand		2,343.48	
			$3,476.10

* Paid from funds provided by designated gifts.

† Balance includes $996.25 in gifts designated for the completion of work on the fifty-year index and the preparation for publication of the "Indiana Men of Science."

(Signed) W. P. Morgan, *Treasurer*.
(Signed) ERSIE S. MARTIN } *Auditors*.
(Signed) KARL S. MEANS }

Bonding Committee. R. C. Friesner reported that the Academy carries with the Hartford Accident and Indemnity Co. bonds in the amount of $2000.00 for the Treasurer and $5000.00 each for the Trustees. These are renewable annually at a total cost of $25.00. Expiration date is November 18. The Executive Committee authorized the continuance of the bonds.

Editor and Publication of Proceedings. R. C. Corley reported an order of 1600 copies of the Proceedings and 7650 reprints.

Research Grant Committee. T. G. Yuncker announced that seven grants are in use at the present time.

Biological Survey. W. E. Ricker reported that the members of the committee were continuing their work.

Fifty-Year Index. R. C. Friesner reported the completion of the indexing. Proof reading would be started within a few days.

Library Committee. W. G. Gingery presented a report prepared by Nellie M. Coats, Academy Librarian. Ten years ago the work of the Academy Library was placed under the jurisdiction of the Catalog Division of the Indiana State Library. In 1935 there were 1030 bound volumes in the Academy Library. In 1945 the total number of bound volumes is 3801, with 217 now in the process of binding. There are 243 titles on the active list of serials. The library received as a gift from

Claude Lomax 13 volumes of ornithological periodicals. In plans presented to the Indiana Economic Council and to the State Building commission, the need for additional space for housing the library was pointed out and a request made for shelving space and for future office space for an Academy headquarters and for committee meetings in the State Library and Historical Building. The Executive Committee accepted this recommendation and authorized the Secretary to send a resolution to that effect to the Secretary of the State Building Commission.

Press Secretary. C. M. Palmer, in co-operation with the Publicity Office of Butler University, sent Academy news release to more than 250 newspapers in Indiana. The photographic file of Academy presidents and other officers is maintained as complete as possible.

Membership. J. E. Switzer presented a tentative report of 60 applications, as the final report and the election of members occur at the dinner meeting.

Junior Academy of Science. H. E. Enders announced the total of 52 Junior Clubs. Biology Club, William Wirt School, Gary, and Junior Academy Club, Franklin High School, Fort Wayne, were presented for affiliation with the Academy.

Relation of Academy to State. F. N. Wallace reported that the Budget Committee recommended an annual appropriation of $1500.00, and the Legislature passed the appropriation.

Relation of Academy to A.A.A.S. No meeting of A.A.A.S. has been held since the last meeting of the Academy.

Nominations. H. E. Enders presented the following names for election as Fellows at the business meeting on Friday: Arthur F. Bentley, William D. Gray, Henry B. Hass, Alfred H. Meyer, and Andrey A. Potter. To the Research Grant Committee, Paul Weatherwax was nominated to complete the term of A. L. Foley, (term expiring in 1946) and H. H. Remmers to replace H. E. Enders, (term expiring in 1945). (It was Dr. Enders' personal request not be continued on the committee.) R. C. Friesner, Chairman, and Scott McCoy were nominated to succeed themselves on the committee of Bonding of Trustees.

Old Business. W. E. Edington made a progress report for the Committee on History of Science in Indiana. T. G. Yuncker, reporting for the committee appointed to canvass the possibility, of securing the affiliation of scientific organizations in Indiana with the Academy of Science, stated that no organization is interested in such affiliation at this time, and added that inasmuch as the method by which an organization may unite with the Academy has been established the members of this committee propose that said committee be discharged and that any officer or member of the Academy be free to suggest such an affiliation when deemed proper.

New Business. J. S. Wright read a letter from Mrs. H. L. Bruner in which Mrs. Bruner had sent a check for the Academy Foundation

Fund in memory of her husband and his interest in the Academy. The gift was accepted and the Secretary instructed to send a letter of thanks and appreciation to Mrs. Bruner.

J. S. Wright read the following resolution to the committee:

A RESOLUTION petitioning Congress to enact laws to effectuate the plans for a memorial to Benjamin Harrison, and to provide the necessary funds therefor.

WHEREAS, the Benjamin Harrison Memorial Commission has transmitted its report in compliance with the provisions of Section 3, Public Law No. 352, Seventy-sixth Congress, approved August 9, 1939, said report having been submitted March 21, 1941, published as House Document 154, Seventy-seventh Congress, first session and referred to the committee on the library for a suitable memorial to Benjamin Harrison;

WHEREAS, the plans as recommended will advance the conservation program in Indiana by at least one generation by accelerating the forest restoration program; and

WHEREAS, the plans are in keeping with sound postwar work; and

WHEREAS, the plan combines wise use of government money with a long range program of investment by creating a memorial of usefulness and beauty; and

WHEREAS, the proposed Harrison Memorial requires the approval of the Congress of the United States to effectuate the plan; Therefore

SECTION 1. BE IT RESOLVED BY THE INDIANA ACADEMY OF SCIENCE, an organization of nearly one thousand members representing the various scientific interests of the state, at its SIXTY-FIRST ANNUAL MEETING hereby petitions the Congress of the United States to enact into law H.R. 4006, which was introduced into the Seventy-ninth Congress, so as to effectuate the plans for a memorial to Benjamin Harrison, and to provide the needed funds for accomplishing the plans as heretofore recommended by the Benjamin Harrison Memorial Commission in its report made to the Seventy-seventh Congress, first session.

SECTION 2. That a certified copy of this resolution be sent by the secretary of the Indiana Academy of Science to the clerk of the house of representatives and to the secretary of the senate of the Seventy-ninth Congress, and to each United States senator and representative from Indiana.

The resolution was adopted and the Secretary instructed to send certified copies of same to the authorities listed in the Resolution.

It was voted to resume the holding of Spring meetings in 1946. Because of World War II no Spring meetings were held in 1943, 1944, and 1945.

The chairman of the Fifty-year Index is to be included on the Academy Budget Committee until the Index is published.

A motion was made by H. E. Enders to strike the following sentence from the By-Laws, Art. 2, Sec. 3: "Of members so nominated a number not exceeding five in any one year may, on recommendation of the Executive Committee, be elected as fellows." The motion was seconded and the recommendation carried, the item to be presented to the General Business Session Friday morning.

A motion was made by T. G. Yuncker that the President of the Academy follow the principle of continuing one member of the Nominating Committee of the previous year, for the sake of continuity of ideas presented in the committee. Motion was seconded and adopted.

Meeting adjourned at 10:10 p. m.

MINUTES OF THE GENERAL SESSION

BUTLER UNIVERSITY, October 19, 1945

Dr. C. R. Maxam, Registrar, Butler University, delivered the Address of Welcome. President Markle responded in behalf of the Academy.

W. E. Edington presented the Necrology.

Minutes of the Executive Committee meeting of October 18, 1945, were read by the Secretary and approved by the Academy. H. E. Enders explained to the General Session the reason for the proposed change in the By-Laws. F. B. Wade moved that the By-Laws be changed as recommended by the Executive Committee. J. F. Mackell seconded the motion. It was voted that the sentence be stricken from the By-Laws.

Following the annual dinner in the Travertine Room, Hotel Lincoln, J. E. Switzer presented ninety-six applications for membership. The Secretary was instructed to cast an unanimous ballot for the ninety-six applicants.

H. E. Enders read the nominations of the committee as follows: *President,* E. F. Degering, Purdue University; *Vice-President,* N. E. Pearson, Butler University; *Secretary,* Winona H. Welch, DePauw University; *Treasurer,* W. P. Morgan, Indiana Central College; *Editor,* R. C. Corley, Purdue University; and *Press Secretary,* C. M. Palmer, Bulter University.

The Divisional Chairmen elected in the sectional meetings for 1946 were announced as follows *Anthropology,* Wm. B. Adams, Bloomington; *Bacteriology,* F. A. Miller, Eli Lilly & Co., Greenfield; *Botany,* J. E. Potzger, Butler University; *Chemistry,* E. F. Degering, Purdue University; *Geology and Geography,* G. D. Koch, Indiana State Teachers College, Terre Haute; *History of Science,* W. E. Edington, DePauw University; *Mathematics,* H. E. Wolfe, Indiana University; *Physics,* K. W. Meissner, Purdue University; *Psychology,* C. C. Josey, Butler University; and *Zoology,* H. H. Vogel, Jr., Wabash College.

C. M. Palmer announced that the Committee on Invitations had accepted the invitation of Indiana State Teachers College, Terre Haute, for the 1946 Fall Meeting of the Academy.

O. B. Christy expressed on behalf of the Academy its sincere appreciation and thanks to the faculty of Butler University, the management of the Hotel Lincoln, to the program committee, the committee on Junior Academy of Science, and to the officers of the Indiana Branch of the Soicety of American Bacteriologists and the Indiana Section of the Mathematical Association of America for their willingness to join in the Academy program.

Vice-President Mackell introduced President Markle who delivered a splendid address on "Biology and the Postwar World."

The 61st annual meeting of the Indiana Academy of Science, with a general attendance of 281 and a dinner attendance of 124, was adjourned.

WINONA H. WELCH, *Secretary.*

TAXONOMISTS MEETING

J. E. POTZGER, Butler University, Chairman

The Plant Taxonomists held their meeting on Saturday morning at Butler University. A. T. Guard, Purdue University, was elected chairman for 1946, and Naomi Mullendore, Franklin College, Secretary.

ENTOMOLOGISTS MEETING

RALPH MORRIS, Assistant State Entomologist, Chairman

Glen E. Lehker, Purdue University, was elected chairman for 1946.

ADDITIONAL NEW MEMBERS, 1944

Bolander, Mr. Lester M., 1226 N. Temple Ave., Indianapolis 1 .. .C
Coon, Mr. Jesse B., 624 E. 8th, Bloomington .... Ph
Edmondson, Dr. Frank K., 716 S. Woodlawn, Bloomington .... As
Feinberg, Mr. Mortimer, Science Hall, Psych. Dept., Indiana U., Bloomington .... Ps
Garst, Miss Virginia L., De Soto .... Bo
Hamilton, Mr. Dan K., 531 Federal Bldg., Louisville 2, Ky..... ..G
Hart, Mr. Donald M., Dept. of Chemistry, Indiana University, Bloomington C
Hire, Dr. Charles, Dept. of Physics, Indiana University, Bloomington..Ph
Hornaday, Mr. Raymond, 578 M. D. Woodruff Place, Indianapolis 1...Ph
Klaer, Jr., Mr. Fred H., 3835 N. New Jersey St., Indianapolis 5.......G
Wynd, Dr. F. L., University of Illinois, Urbana, Illinois ....Bo
Zicroff, Sister Gertrude Marie, O.S.F., 3600 Cold Springs Rd., Marian College, Indianapolis 44 .... M

NEW MEMBERS, 1945

Adams, Dr. S. Clifford, Box 194, Hanover.........................G
Akers, Mr. Eugene, 621 Highwood Ave., Greencastle...............Bo, C
Bailey, Mr. James C., 246 N. Smart St., Greenwood..............General
Barton, Mrs. Mary F., 6048 Carrollton Ave., Indianapolis.........Nature
Bechert, Mr. Charles H., 1207 N. Wallace St., Indianapolis. .Hydrology
Bergdall, Miss Irene F., 2306 College Ave., Huntington............ M
Bogarosh, Mr. Peter L., 318 Warren St., Phillipsburg, New Jersey.. .Bo
Bohnenblust, Prof. Henri Frederic, 714 East 9th St., Bloomington ....M
Buehler, Mr. John A., Chemistry Dept., Indiana U., Bloomington... ..C
Burkett, Prof. Howard B., 325 Highfall Ave., Greencastle. C
Carnahan, Prof. Walter H., 708 Vine St., West Lafayette............M
Christian, Dr. John Edward, 825 N. Main St., West Lafayette.........C
Christman, Mr. John F., 525 South 6th St., Terre Haute..............C
Churchill, Mr. Paul K., 2928 Washinton Blvd., Indianapolis 5.........Ph
Clark, Mr. James A., 700 Montomery Ave., Jeffersonville..............E
Cole, Dr. Versa V., 1040 W. Michigan St., Indianapolis..........Pharm.
Conklin, Dr. Raymond L., 1906 E. Jackson Blvd., Elkhart ...Ba, C, Ps
Cook, Dr. Donald J., 415 E. Walnut, Greencastle C
Cougill, Mr. Kenneth R., 811 Berkley Road, Indianapolis . Conservation
Cox, Mr. Alvalon Conway, 2948 Indianapolis Ave., Indianapolis.......Ph
Deese, Mr. James, 1357 E. Tenth St., Bloomington...................Psy
Deiss, Prof. Charles F., 819 East 8th St., Bloomington................G
Delks, Miss Patricia, 31 N. Bolton Ave., Indianapolis 1..............A
DeMoss, Prof. Lowell H., Central Normal College, Danville...........B
Elbinger, Mrs. Rebecca L., 2521 Elmhurst, Detroit, Michigan..........C
Everts, Miss Marilyn, 326 W. Crawford St., Elkhart................C-B
Goebel, Mr. Harold John, 701 W. Packard Ave., Fort Wayne..........B

Golbach, Mr. Richard, 4703 Guilford Ave., Indianapolis 5.... Everything
Grandy, Mrs. Gladys E., 717 E. 52nd St., Indianapolis.... Gen Sci
Gries, Dr. George A., 901 W. Stadium Ave., West Lafayette.... Bo
Hadley, Prof. Alden H., 203 W. High St., Mooresville .... B
Hanske, Mr. Carl F., 901 N. Bolton Ave., Indianapolis.... B-C
Harrison, Mrs. Anne Butler, 48 S. Downey Ave., Indianapolis 1.... Orn
Heppel, Miss Ruth E., 626 S. Norman Ave., Evansville 14.... Bo
Higinbotham, Dr. Noe, 311 North Williams St., South Bend 5 .... Bo
Hinchman, Mr. Max, 303 W. Fourth St., Greenfield .... B
Hine, Dr. Maynard K., 327 Buckingham Drive, Indianapolis... Dentist
Huddleston, Mrs. Frances, 557 Jackson St., Gary .... B
Hurlbut, Miss Zylpha D., 121 N. Tillotson Ave., Muncie .... B
Hyde, Miss Julia, 666 E. Jefferson St., Franklin .... B-C
James, Prof. Charles M., 136 DeHart St., W. Lafayette.... Z
Jeffers, Miss Vivian D., 337 Elm Street, Lawrenceburg.... B
Kelly, Miss Mary Frances, 5932 Oak Avenue, Indianapolis .... A
Ketchum, Mrs. Helen M., 217 Park Ave., Elkhart .... Bac
Knapp, Mr. Virgil R., Zionsville.... E
Krumholz, Dr. Louis A., 730 E. Hunter Ave., Bloomington.... Z
Larson, Dr. Raymond G., 255 S. College Ave., Valparaiso.... C
Liaptcheff, Mr. K. K., Dept. of Zoology, Indiana U., Bloomington.... Z
Lillard, Prof. Richard G., Route 3, Bloomington.... Geog
Livingston, Mr. William Arnold, 427 S. Henderson St., Bloomington.. Psy
Lorz, Dr. Albert P., R.R. 10, Lafayette.... Genetics
Malm, Dr. Marguerite, Union Bldg., Indiana State Teachers College, Terre Haute .... Psy
Martindale, Miss Evelyn C., Box 33 Manchester College, North Manchester .... C-B
McClain, Mr. John A., 601 N. East, Greenfield .... B
McCreery, Mr. Gene S., 402½ S. Talley Ave., Muncie.... C-B
McDougal, Mr. Russell, 2515 Deming St., Terre Haute.... C, B, Ph
McKinney, Mr. Gordon R., 925 Eugene St., Indianapolis 8.... Z
Meibohm, Mr. A. W., 455 South Greenwich, Valparaiso.... C
Meissner, Dr. K. W., 216 South Chauncey Ave., West Lafayette.... Ph
Morris, Dr. D. W., 2730 Wilson Drive, Terre Haute.... Speech
Olsen, Miss Florence M., 705 5th St., Devils Lake, North Dakota.... Ph
Passel, Mr. Charles F., Dept. of Geology, Indiana U., Bloomington.... G
Peak, Mr. Philip, 610 North Faculty, Bloomington.... M
Phillips, Mr. William F., 826 Collett Ave., Terre Haute.... C
Prange, Mr. Henry C., 5721 Haverford Ave., Indianapolis.... Bo, G
Pruett, Mr. John Robert, 301 N. Jefferson St., Bloomington.... Ph
Rowe, Dr. Edward J., 5819 E. Washington St., No. 8, Indianapolis 1. C
Sanders, Miss Dorothy W., Sandborn.... B
Schmidt, Dr. Bernardine C., Special Education Clinics IST College, Terre Haute .... Psy
Schwarz, Mr. W. M., 412 Ballantine, Bloomington.... Ph
Scott, Mr. Donald C., 203 S. Washington, Bloomington.... Z
Sheehan, Rev. Robert J., Dept. of Biology, Univ. of Notre Dame, Notre Dame .... Z

Skinner, Dr. B. F., 824 Sheridan Rd., Bloomington .... Psy
Sprinkle, Mr. Howard B., R.R. 3, Muncie C
Staab, Rev. C. J., St. Joseph's College, Collegeville . ...Ph
Stone, Mr. G. Raymond, 214 E. 6th St., Bloomington .. ... .Psy
Stuart, Mr. Elmer H., R.R. 6, Box 636, Indianapolis 44...............C
Sturm, Dr. R. G., 1200 North Grant, West Lafayette . ..Eng
Suttle, Dr. John F., 508 E. 4th St., Bloomington.......... C
Thomas, Prof. Tracy Y., North Fee Lane, R.R. 2, Bloomington. .. . M
Toabe, Miss Ruth, 522 East Third St., Bloomington......... .... Bact
VerHoef, Miss Shirley, 152 S. Home Ave., Franklin..................B
Volk, Dr. N. J., 865 N. Salisbury, West Lafayette .. . Agri
Whitesel, Miss Grace, Butler University, Indianapolis ...... Home Econ
Wiggam, Dr. Albert E., Box 200, Vernon. . . . . .B
Williams, Miss Jane, 4231, Carrollton, Indianapolis 5... .. ... General
Williams, Prof. Kenneth P., 523 E. Third St., Bloomington . .. .. .M
Williams, Miss Mary I., 316 Berkley Road, Indianapolis 8.... ......Eng
Wilson, Mr. Francis H., 1513 Alabama St., Lafayette... .. ... Anthro
Wirsching, Mr. Robt. F., 727 Nottingham St., Indianapolis. . . .Engin
Wood, Miss Allyn Louise, 2502 North Alabama St., Indianapolis 5...B
Woofter, Dr. J. A., Taylor University, Upland....... ....Psy
Wyse, Prof. Olive G., 1810 South Main St., Goshen........ ...Home Ec

JUNIOR ACADEMIES

Biology Club of William A. Wirt School, Grand Blvd. at Birch St., Gary B
Franklin Junior Academy of Science, Archer and St. Mary's Ave.,
Fort Wayne ....

INDIANA JUNIOR ACADEMY OF SCIENCE

OFFICERS FOR 1942-1945*

President: Mary Ann Stout
Elkhart, Indiana

Vice President: Lloyd Nevel
Mishawaka

Secretary: James Smith
Central High School, South Bend

OFFICERS PRO TEM FOR 1945

President: Richard Rhems
Central High School, South Bend

Vice President: Richard Gumpper
Elkhart, Indiana

Secretary: Joyce Raih
Central High School, South Bend

Members of the Council: (Elected by Club Sponsors)
J. H. Otto (1943-1946); Prevo Whitaker (1944-1947);
Roy McKee (1945-1948); Darl Wood (1946-1949);
Ruth Wimmer (1945-1950)

* No meetings were held during the war period.

PROGRAM OF THE THIRTEENTH ANNUAL MEETING

Butler University, October 20, 1945

9:00 A.M., Jordan Hall

Exhibits, in the Zoology Laboratory, 9:00 to 10:00 A.M.

Papers, 10:00 A.M. to 12 M.

1. "Shades of the Future"—Phyllis Gouker, Senior High School, Elkhart
2. "Collecting and Mounting Insects"—Bill Kwolek, Lew Wallace High School, Gary
3. "Insects"—Edward Mockford and Dale Rice, Shortridge High School, Indianapolis
4. "Moths and Butterflies"—Dorothy Webb, Shortridge High School, Indianapolis
5. "The Model Airplane"—James McNair, Crispus Attucks High School, Indianapolis
6. "Chemiluminescence"—John Martin, Shortridge High School, Indianapolis

Business Session, and Continued Scientific Program, 1:00 to 3:30 P.M.

1. Colored Motion Pictures—Dr. Howard H. Vogel, Wabash College
   Birds of Indiana
   Hatching of Bobwhite Quail Eggs
   Natural History of Indiana—Emphasis placed on social behavior of local birds and mammals
2. "A Review of Atomic Transformation produced by Nuclear Bombardment"—Lloyd Hill, Technical High School
3. "Economic Importance of Some Common Birds"—Louis Wuellner, (Lantern), Technical High School, Indianapolis
4. "Back Tracing the Wisconsin Glacier"—Francis Weber, Shortridge High School
5. "Smaller Rodents of Indiana"—Steve Wainwright, Shortridge High School
6. Talk, M. M. Williams, Club Sponsor, Bloomington High School
   Report on the Progress of the Indiana Junior Academy of Science, by Dean Howard E. Enders, State Sponsor

MINUTES

The thirteenth annual meeting of the Indiana Junior Academy of Science was held Saturday, Ocober 20, 1945, in Room 131, Jordan Hall, Butler University, Indianapolis.

Dr. Howard E. Enders, State Sponsor of the Indiana Junior Academy and Dean of the School of Science, Purdue University, greeted the members of the Junior Academy and introduced the *pro tem* officers selected by the Council:

President, Richard Rehms, Central High School, South Bend, Indiana

Vice President, Richard Gumpper, Elkhart, Indiana

Secretary, Joyce Raih, Central High School, South Bend, Indiana

The president *pro tem* opened the meeting by calling for the minutes of the previous meeting. They were read and approved (none being held during the period of the war), with the suggestion by Dean Enders that the minutes of the two annual meetings of the Indianapolis section of clubs be embodied in the present minutes.

The first number on the program was given by Phyllis Gouker, Senior High School, Elkhart, Indiana, on "Shades of the Future." She gave a very interesting talk on the trees of the city of Elkhart, with excellent plans for the future, additions through the help of her science club. She illustrated her talk by means of charts to cover the main points in relation to the care of the trees that have been set out.

The president then introduced Bill Kwolek of Lew Wallace High School, Gary, who gave a very interesting talk on "Collecting and Mounting Insects." Dean Enders commended Bill and pointed out the good services the clubs of the Indiana Junior Academy of Science have rendered to its members and in this respect cited the outstanding progress made by another particular student. He urged all of us to follow through with our interests in science.

The president then called on Edward Mockford and Dale Rice, both of Shortridge High School. Edward began his talk by explaining the meaning of the word "insect" and told how insects are classified and given their names. He also explained the instruments used in collecting different kinds of insects. Dale Rice then took over and explained the classification of the orders of insects by means of a chart he drew on the blackboard.

"Moths and Butterflies" was the next topic, discussed by Dorothy Webb, of Shortridge High School. She explained how and why she became interested in moths and butterflies, and explained many interesting features by pointing them out on the species which she had mounted.

The fifth speaker of the morning was James McNair of Crispus Attucks High School who represented the CPA of Indianapolis. His talk was on the "Model Airplane." He showed us a very interesting model which he had made, and explained the parts, and principles of the model airplane.

The president introduced John Martin of Shortridge High School, who gave us a series of experiments on Chemiluminescence, in a completely darkened hall to which the group adjourned for this purpose. A series of very striking experiments lighted the dark hall through a range of colors and intensities.

The meeting adjourned for luncheon.

The afternoon session was held at 1:00 P.M., Jordan Hall. Miss Ruth Wimmer, Sponsor of the Phi Chem Club, Elmhurst High School, Fort Wayne, was elected to the Council by the councilors to succeed Mr. H. H. Michaud, former sponsor of the Nature Club, North Side High School, Fort Wayne. Election of officers for the next year was then held. Dean Enders read the list of nominees and the club members balloted for and elected the following officers for the year 1946:

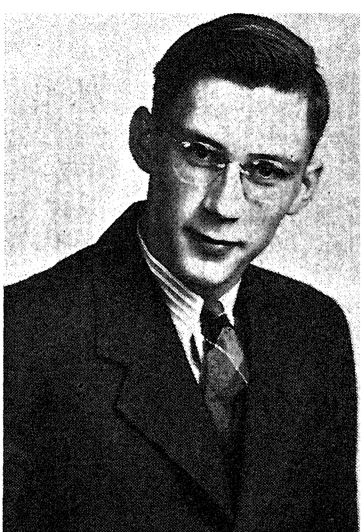
President: Charles Giffen, Phi Chem Club, Elmhurst High School, Fort Wayne

Vice President: Robert Reinhold, Central High School, South Bend

Secretary: Robert Lovett, Science Club, Mishawaka

The next part of the program was a series of motion pictures, in color, shown by Dr. Howard H. Vogel, Jr., Professor of Zoology at Wabash College, on birds and other animals in Indiana. Emphasis was placed on social behavior of local birds and mammals.

The president then introduced Lloyd Hill, who gave us a review of the atomic transformation by nuclear bombardment. He confined most



Bill Kwolek

Phyllis Gouker

of his talk to the neutrons of the atoms. He also explained the true meaning of radio activities of the elements.

The Council announced its choice of Phyllis Gouker of Elkhart, and Bill Kwolek of Gary, as the "Best Girl" and "Best Boy," respectively, to recommend for Honorary Membership in the American Association for the Advancement of Science.

The president then introduced Louis Wuellner, of Technical High School, who talked on "The Economic Importance of Some Common Birds." He showed pictures, by lantern, and pointed out their main characteristics of the different birds shown.

Francis Huber, Shortridge High School, talked on "Back Tracing the Wisconsin Glacier." He flashed the map of the middle western states and traced the route of the glacier.

The president introduced Steve Wainwright of Shortridge High School, who talked on "Smaller Rodents of Indiana." He told of the characteristics of the white-footed mouse, field mouse, buff-breasted mouse, leming mouse, pine mouse and the jumping mouse.

The sponsor, Mr. M. M. Williams, of the Bloomington High School, told how the members of his club developed a record of high achievement and advised us to plan our projects with our sponsor.

Dean Enders told us of the origin of the Indiana Junior Academy of Science and of the many benefits we can gain by being members. He told us that fifty-four clubs belong to the Junior Academy. Suggestions were made to keep in touch with other clubs, by means of some kind of Round Robin letter of communication between the several clubs.

The meeting was adjourned at 3:30 P.M.

JOYCE RAIH, *Secretary Pro Tem,*
Central High School, South Bend.

MEMBER CLUBS

INDIANA JUNIOR ACADEMY OF SCIENCE

Town	*Name and School*	*Date Organized*	*Sponsor*
Anderson	Science	1936	M. J. Brozier
Bedford	Phi Pi Chi	1941	W. D. Prather
Bloomington	*General Science, Jr. H. S.	1931	M. M. Williams
	University School-Science	1938	W. B. Miner
Cambridge City	Tri Science	1934	J. L. Bozarth
Crawfordsville	*Audubon Society, Jr. H. S.	1931	Emmet Stout
East Chicago	Edison Club, Roosevelt H. S. (Inactive)	1935	Harry Apostle
Elkhart	Junior Academy		N. E. Adams, Evelyn Wagoner
Fort Wayne	*Geography Council, North Side H.S.	1932	
	Nature Club, North Side H. S.	1936	Vesta Thompson
	Jr. Academy Club, Franklin H. S.	1945	Wm. A. Willer
	Phi Chem Club, North Side H. S.	1937	H. A. Thomas
	Phy Chem Club, Elmhurst H. S.	1935	Ruth Wimmer, Ralph Young
	Nature Club, Central H. S.		Iva Spangler
Gary	Biology Club, Lew Wallace H. S.	1935	Lola Lemon
	Klub Kem Club, Lew Wallace H. S.		Mrs. Helen Mackenzie
	Biology Club, Wm. A. Wirt School	1945	Mrs. Frances Huddleston
	T Square Club, Tolleston H. S.	1944	Olive Leskow
Gas City	Science Club	1936	Roy McKee
Greencastle	Science Club	1936	F. N. Jones
Guilford	Science Club	1936	L. B. Willis
Hammond	Edison Acad. of Science, Edison School	1938	
Indianapolis	*Crispus Attucks H. S.—Biology, Chemistry, Zoology and Radio	1931	Mrs. Kuykendall, A. C. Cox, G. W. Wade, L. C. Parker
	George Washington H. S. Science Club	1937	J. H. Otto
	*Technical School—Nature Study Club	1932	C. F. Cox
	*Technical School—Physics Club		Chas. Brosey
	Technical School—Chemistry Club	1942	Mr. Bolander
	*Shortridge H. S.—Chem. Club	1931	Wm. Johnson, Messrs. Wade, Block,
Lafayette	Biology Club, Jefferson H. S.	1939	Miss Wilson
Lawrenceburg	Phi-Bi-Chem	1939	H. P. Harrison
Lowell	Science Club	1935	C. N. Seeright
Madison	Science Club	1938	Evans Cottman
Marion	Science Club	1936	Pauline Mayhug, L. L. Strickland

Town	*Name and School*	*Date Organized*	*Sponsor*
Mishawaka	Science Club	1936	Darl F. Wood
Montmorenci	Jr. Academy of Science	1933	
Mooresville	Science Club	1936	Fitzhugh Lee
Muncie	Science Club, Jr. H. S. (Blaine)	1934	J. D. Young
New Albany	Jr. Academy of Science, Jr. H.S.	1935	Gladys Knott
North Madison	*Hilltop Nature Study Club	1931	V. Shoemaker
N. Terre Haute	Otter Creek Jr. Acad. of Sci.	1939	Prevo Whitaker
Paoli	Science Club	1935	
South Bend	Central H. S.	1939	
	Central Junior Academy		V. C. Cripe
(a)	Junior Izaak Walton Club		A. L. Smith
(b)	Chemistry Club		F. S. Sanford
(c)	Junior Audubon Club		Arthur L. Smith
Sullivan	Camera Club		Ruth Hinkle
Terre Haute	Jr. Science Club (Laboratory School)	1939	G. Shontz
	State Discovery Club, Sr. H. S.	1939	W. Woodrow
	Laboratory School		V. C. O'Leary
Tipton	Nature Club	1935	W. D. Hiatt
Valparaiso	*Sciemus Club	1931	C. O. Pauley
Wabash	Science Club	1936	R. D. Black
W. Lafayette	Biology Club	1933	Anna Inskeep

* Charter Clubs.

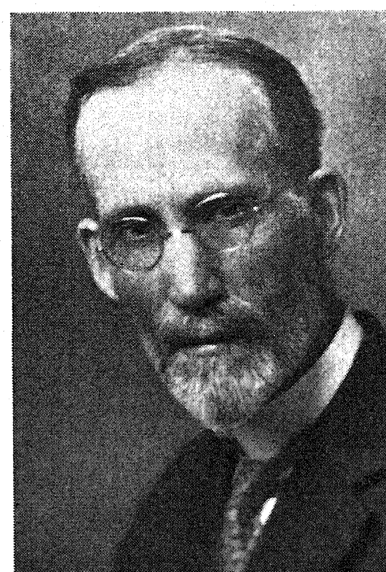
NECROLOGY

WILL E. EDINGTON, DePauw University

HENRY LANE BRUNER

Knox County, Illinois — Indianapolis, Indiana
January 10, 1861 — March 17, 1945

When Henry Lane Bruner came to Butler University in 1892 as Professor of Geology and Biology he came at a time when Indiana was losing many of its finest scientists. David Starr Jordan had just gone to Stanford University the preceding year, taking with him John C. Branner, Joseph Swain, Oliver P. Jenkins, and others. Barton W. Ever-



mann had just left to become chief of the United State Bureau of Fisheries, and John M. Coulter had completed one year as President of Indiana University and was to leave the State the next year to accept the presidency of Lake Forest University. Both Jordan and Evermann had held positions at Butler University. Jordan was succeeded at Butler in 1879 by Oliver P. Hay, who had been Bruner's teacher at Abingdon College, and when Hay resigned in 1892 because of differences of opinion

with the college authorities on the theory of evolution, he was succeeded by his old pupil, Bruner. So Henry Lane Bruner came to Butler in an atmosphere charged with controversy. Also he immediately came into contact with that fine group of scientists, W. S. Blatchley, Amos W. Butler, Stanley Coulter, Carl H. Eigenmann, J. C. Arthur, W. A. Noyes and David W. Mottier, all enthusiastic members of the Indiana Academy of Science. Dr. Bruner joined the Academy in 1892, and at the time of his death he was the oldest active member in the Academy, both in age and years of membership.

Henry Lane Bruner was born of pioneer parents in Knox County, Illinois, on January 10, 1861. After completing the work of the public schools he entered Abingdon College, now known as Eureka College, from which he was graduated in 1880. He spent the next year in graduate study at Yale University and then returned to Abingdon College as Professor of Natural Science where he remained for five years. During that time he spent his summers at Woods Hole, Massachusetts, as Assistant United States Fish Commissioner. After leaving Abingdon, he held a similar position at Drake University before coming to Butler in 1892 as Professor of Biology. Several years later he went to Germany where he studied under the great comparative anatomist, Wiedersheim, at the University of Freiburg and received the Ph.D. degree in 1896. He was Harrison Fellow at the University of Pennsylvania during 1910-1911. He lectured before the Indiana Dental College from 1913 to 1917, and was on the summer staff at Indiana University in 1920. With the reorganization of the Natural Science Department at Butler in 1919, Dr. Bruner was made Professor and Head of the Department of Zoology, which position he held until his retirement in 1938 as Emeritus Professor of Zoology. He was also Director of Graduate Studies at Butler from 1932 until his retirement.

Dr. Bruner was active in Academy affairs. He was editor of the *Proceedings* for 1909 and 1910. At the meeting of the Executive Committee in 1916 he spoke on the matter of establishing an Academy Research Foundation, and he was appointed chairman of a committee to make a report the following year. Favorable action was finally taken in 1919, following a revised report by Dr. Bruner, R. W. McBride and John S. Wright, and Dr. Bruner was appointed one of the six Directors of Research for 1920. The Academy elected him as its President in 1920. In his Presidential Address on "Biological Laws and Social Progress," he deplored man's violation of the laws of progressive evolution. He was a member of the Academy State Library Committee from 1931 to 1933, and of the Committee for Bonding Trustees from 1932 until ill health forced him to resign ten years later.

Dr. Bruner occasionally presented papers before the Academy but his primary interest was in teaching. He was the author of seven published papers on comparative anatomy, embryology and physiology, and of a college textbook, "Laboratory Directions in College Zoology," which has passed through three editions.

He was a Fellow of the American Association for the Advancement of Science and of the Indiana Academy of Science. He was also a mem-

ber of the Society of Zoologists, the Eugenics Society, and the Iowa and New York Academies of Science.

Dr. Bruner faithfully served Butler University forty-six years as an active worker and in grateful acknowledgment that University conferred the Sc.D. degree on him in 1932. The Academy honored him in 1944 as one of its Fifty-Year Members. He will be long remembered as a fine, dignified, scholarly gentleman whose influence was ever wielded for the betterment of mankind. Never officious, but always kindly, he represented the best in science and human relationships.

CLARENCE EDMUND EDMONDSON

Ellettsville, Indiana — South Pasadena, California
April 9, 1883 — December 15, 1944

College administration has become so complex during the past quarter of this century that most of the work of administration formerly done by the Faculty is now done by deans of one kind or another. Much of the social relationships, not covered by tradition, is controlled by Deans of Men and Deans of Women, and often these deans are more intimately known to the students and alumni, and more widely known to the public at large, than the administrative heads. To be a successful Dean of Men requires a fine personality, a high degree of intellectual integrity, and a genuine understanding of and sympathy with student problems, as well as outstanding ability to influence and control student sentiment and social relationships. Dean Clarence E. Edmondson had all these qualities and for twenty-five years was known as the friend and confidant of Indiana University students. Affectionately known as "Pat," his retirement at Indiana University in 1944 was received with keen regret by Faculty, students and alumni alike.

Dean Edmondson spent almost his whole life in Indiana. Born at Ellettsville, April 9, 1883, just seven miles from Bloomington, he received the usual public school education and then entered Indiana University, graduating in 1906. He spent the next three years teaching in Crawfordsville High School. Returning to Indiana University in 1909 as a graduate assistant in physiology, he received the A.M. degree in 1912, and was immediately made an instructor, which rank he held for four years. In this period he completed the work for the doctorate and received his Ph.D. degree in 1914. He was promoted to assistant professor in 1916, and in 1919 was made Associate Professor of Hygiene in the Medical School and appointed Dean of Men. He received the rank of professor in 1925, and was made Head of the Department of Hygiene. He continued his work in both capacities until he was granted a leave of absence in 1943, and finally retired in July, 1944. He and Mrs. Edmondson, who was also a member of the Faculty of Indiana University, went to South Pasadena, California, where he passed away on December 15, 1944.

Early in his career Dean Edmondson had some time for research and he published several papers on the physiology of the thyroid and

thymus glands. He joined the Academy of Science in 1912 and continued his membership to the end. He was a Fellow in the American Association for the Advancement of Science, a member of both Phi Beta Kappa and Sigma Xi, and also of the Mayflower Society. He served as President of National Association of Deans of Men in 1932.

He was a man of broad interests. He was scoutmaster of one of the first troops of Boy Scouts organized in Bloomington. A master of billiards he could hold his own with all comers, students and Faculty alike, and he won the national Faculty straight-rail billiards championship of the United States in 1936 and held it until 1944. He was an excellent shot and spent much of his spare time hunting and trapshooting.

Dean Edmondson was an excellent teacher and administrator. His lectures were characterized by clarity, sincerity and absolute honesty. Firm but just in dealing with students he had their confidence and respect because they knew he had the student slant on student problems. Known and loved by thousands of students and alumni of Indiana University as a friend and adviser, his memory will long be cherished.

ARTHUR LEE FOLEY

Hancock County, Indiana	Tampa, Florida
February 22, 1867	February 13, 1945

When death claimed Arthur Lee Foley, on February 13, 1945, the Indiana Academy of Science lost one of its most loyal, prominent and influential members, and Indiana University lost another of its few remaining distinguished Faculty members whose careers in science extend back to the time of the presidency of David Starr Jordan. Although Dr. Foley retired from teaching in 1938 with the title of Emeritus Professor of Physics, he nevertheless remained vigorous and active until the day of his death which occurred two weeks after he and Mrs. Foley had gone to Tampa, Florida, to visit his sister.

Arthur Lee Foley was born in Blue River Township in Hancock County, and in his later years he regularly returned to this township where he owned a farm and where he was finally laid to rest. As a child he attended the country schools, and at the age of fifteen he entered Central Normal College at Danville where he spent two years in study. He began his teaching in 1884 in the public schools of Vivalia. The following year he was married and returned to his home county as principal of the Cleveland school. Two years later he took a position in the Johnsonville, Illinois, public schools and remained one year. In 1888 the Foleys went to Bloomington where young Foley entered Indiana University. Two years later, after receiving the A.B. degree, he was appointed an instructor of physics which position he held for one year while he worked for the Master's degree which he received in 1891. He was immediately appointed Associate Professor of Physics which rank he held until 1897 when, at the age of thirty, he was made Professor and Head of the Department of Physics. During his tenure as associate

professor he did graduate study in 1894 at the University of Chicago, and later entered Cornell University as a Fellow where the Ph.D. degree was conferred on him in 1897. He went to Europe in 1908 and studied at the University of Berlin. At the time of his retirement in 1938 he had completed fifty years of intimate association with Indiana University, forty-one years of this as Head of the Department of Physics.

Dr. Foley was a man of tremendous energy who had little patience with superficiality and sham, and he was sharp and outspoken in his denunciation of all such. But in his personal relationships he was most genial and charming. He was at his best in the class room and his lectures were illustrated very completely and the subject matter was presented in a most interesting way.

He enjoyed a national reputation as a physicist, being starred in *American Men of Science*. At Indiana University he was Waterman

Research Professor from 1917 to 1925. During this same period he was Director of Research for Affiliated Colleges of Indiana. He was chairman of the research committee of the Indiana State Council of Defense from 1915 to 1918, and Director of the United States Radio School at Indiana University in 1918. He was also a member of the Acoustical Committee of the National Research Council from 1919 to 1921.

Dr. Foley joined the Indiana Academy of Science in 1894 and was made a Fellow in 1897. He edited the *Proceedings* in 1907, was twice vice-president, in 1908 and 1914, and was chairman of the Academy Research Committee from 1924 until the time of his death. He was President of the Academy in 1909 and presided at the Twenty-fifth An-

niversary meetings of the Academy which were attended by a large number of the greatest scientists at that time in the United States. Dr. Foley's presidential address was entitled "Recent Progress in Physics," and other speakers on the program with him were Harvey W. Wiley, John M. Coulter and David Starr Jordan. In the sectional meetings papers were given by H. A. Huston, B. W. Evermann, Charles W. Greene, C. A. Waldo, Severance Burrage, W. A. Noyes, A. H. Purdue, J. Rollin Slonaker, D. T. MacDougall, J. C. Arthur, Frank D. Kern, Katherine Golden Bitting, Mel T. Cook, O. P. Hay, C. H. Eigenmann and Charles C. Deam. In his address it is worth noting, in the light of the recent atom splitting discoveries, these prophetic words which show Dr. Foley's deep insight. After discussing the discoveries and theories of the molecular structure of matter, the electrical nature of matter, and the dependance of mass upon velocity, Dr. Foley went on to say: "Certain it is we are face to face with energies of which no one even dreamed a few years ago. Whether we call this energy intra-atomic, sub-atomic, inter-elemental or some other name, we know certainly that it exists, and that it exists in quantities far beyond the power of man's mind to comprehend. Man hopes some day, somewhere, somehow, to discover the means of unlocking this infinite storehouse. If this discovery is ever made, all the others which man has made will pale into insignificance beside it." Thus Dr. Foley spoke thirty-six years ago.

It was not uncommon for Dr. Foley to present three or four papers and notes at an Academy meeting. He was the author of some ninety published papers. His principal research was in the field of acoustics, but his interests covered the whole field of physics, subjects of his papers ranging from "Tenacity of Gelatine," "Synchronous Leaping of Fish," "Four Wheel Brakes," to "Rockets or Rackets" and "After the War 'Transportation.'" He was the inventor of numerous acoustical and mechanical devices and he served as a consulting acoustic engineer for radio and phonograph companies and manufacturers of sound absorbing materials. His classic experiments on locomotive whistles were dramatized by the University of Chicago in "Human Adventure" some years ago, and resulted in an improvement in the location and design of locomotive whistles. He wrote a textbook "College Physics" which has been used by over three hundred colleges and has passed into the fourth edition. Thousands of copies of it were used in the United States Army training programs.

Dr. Foley was a Fellow of the American Association for the Advancement of Science, and he held memberships in the American Physical Society, Acoustical Society of America, American Association of Physics Teachers, Sigma Xi and Phi Beta Kappa.

Central Normal College honored him in 1941 with the degree of Litt.D., and at the 1944 meeting of the Indiana Academy of Science special honor was paid to him as one of the three living active fifty-year members. Dr. Foley seldom missed a meeting of the Academy and in his later years he was nearly always accompanied by Mrs. Foley.

Certainly the State of Indiana owes much to Dr. Foley who served the youth of the state so well. With his passing the Academy has lost

another tie with the days when Indiana was noted for its scientists. He has gone to join the "Giants of Those Days."

CLARENCE O. WARNOCK

Indianapolis, Indiana — Indianapolis, Indiana

February 25, 1886 — December 13, 1943

Clarence O. Warnock was a most successful business man who pursued science as a hobby. A citizen of Indianapolis all his life, he graduated from Manual Training High School, and became an apprentice in electrical work. Later he traveled for a while as a representative for two theatrical firms. However, being interested in automobiles, he began his automotive career as a toolmaker, after having spent several years in the experimental department of the Marietta Glass Company. He worked for various individuals and companies before organizing his own company in 1917, which became the C. O. Warnock Company, one of the oldest Ford dealers in Indiana. He was much interested in the 500-mile Speedway Races and at one time worked for Ray Harroun, a one time winner of the race.

However, after he had firmly established his company and had more leisure time he became interested in postage stamps and Mexican archaeology as hobbies. In all he made almost thirty trips to Mexico to study the ruins there. He became an authority on Mexican archaeology and at the time of his death he owned a very valuable collection of Mexican relics and pottery. He had many friends in Mexico and had just returned from a trip there three weeks before he passed away from a heart attack.

Mr. Warnock was one of the leading automobile dealers in Indianapolis and a public spirited citizen. He had served for five years as president of the Indianapolis Automobile Trade Association, and he was active in the National Automobile Dealers Association, The Indianapolis Chamber of Commerce, and the Better Business Bureau. He was a 32nd degree Mason and a member of the Shrine. He belonged to the Indianapolis Stamp Club. He joined the Indiana Historical Society in 1929 and became a member of the Indiana Academy of Science in 1935.

The Academy has need of more members from the business world, men and women who have the leisure time and enthusiasm to study some phase of science as a hobby. Such hobbies should be encouraged, for men like Mr. Warnock have made and can make a distinct contribution to scientific advancement. It is to be sincerely regretted that Mr. Warnock was called away when his service to science and the Academy could have been so effective.

PRESIDENTIAL ADDRESS

Biology and the Post-War World

MILLARD S. MARKLE, Earlham College

The world looks confidently to all the fields of science to create in the post-war period a bright new world, replete with new comforts and conveniences. Some of these innovations the layman definitely envisions; others he vaguely comprehends and still others he cannot describe, but he is sure that science can provide them, though the methods are as little understood as if the work were done with a magic wand. New foods, new gadgets fulfill too often his conception of the abundant life.

Biological science will undoubtedly proceed to develop, along with the other sciences, many lines of progress already well begun. We may expect that the methods used in the spectacular development of hybrid corn will be employed in securing better yields and quality of many domestic crops. Explorers will continue to bring in many foreign plants to supplement the ones we now raise. More rapid transportation by plane will bring to northern tables many new and delectable tropical foods now little or not at all known. New woods and fibers will be used. The further development of animal breeding will provide more efficient production of meat and other animal products. The increased use of plastics and other products of organic origin will encourage the production of new crops in the temperate zone and will turn the attention of northern nations to the tropics, where plant crops grow throughout the year.

The complex developments in the field of health will continue. New antibiotic substances may exceed penicillin in effectiveness; new chemotherapeutic drugs may surpass the sulfa-compounds. A better understanding of tropical diseases, through an increased knowledge of parasitology, will increase the safety of travel and vastly improve the social and economic status of tropical peoples.

But, however bright the new world may appear on superficial thought, and however diligent technical scientists may be, thinking persons all over the world view the future with misgiving, even dread.

Harold Fey recently said[1], "We are the most saddened, bewildered and frightened victors in the history of the world. If Concord's shot was heard round the world, the blast at Hiroshima has shaken a ghost in every closet."

With what satisfaction can we anticipate a world as a habitation for future generations if recurring and ever more destructive wars blast the material and cultural accumulation of the ages and the idealism of social and national groups and mark for their victims the finest individuals of each generation?

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1. Christian Century, Sept. 26, 1945.

No sooner had the atomic bomb been used than a clamor ensued to have it outlawed. Even the scientists who developed it are asking that it be put under international control. Some justify its use as a means of making unnecessary the invasion of Japan, thus saving many American lives. Others claim that Japan had already been defeated and that surrender must soon have come. So perhaps it had no justification, even on the basis of military expediency. It is a two-edged sword. Its secret cannot long be kept. With robot planes and atomic bombs, even our interior cities are wide open to attack, by an enemy anywhere in the world. Since more than ever before the advantage will come to the nation that strikes first, each must be fully prepared and constantly on the alert.

In a recent conversation, a scientist connected with the development of the atomic bomb is said to have remarked, "I am sorry it worked." A military man replied, "Amen."

Speakers and writers everywhere are urging the necessity of moving as rapidly as possible toward a fuller international organization than Bretton Woods, Dumbarton Oaks or San Francisco have provided. Wendell Willkie wrote of "One World." Freda Kirchwey heads a recent magazine article "One World or None."

Until the modern period, national and racial groups were separated by natural boundaries. Even as late as 1904, Russia and Japan could wage a war without its spreading beyond eastern Asia. A generation ago, Jules Verne's "Around the World in Eighty Days" was read with amusement; now a routine flight around the world is made in eight days.

Early wars were fought with primitive weapons—bare fists, then stones and clubs, then bows and arrows. Gunpowder revolutionized warfare and made coats of mail antique. Guns of longer range, explosives of greater power, airplanes of greater range and speed add constantly to the destructiveness of war. Now we have leaped at one bound into a new era with the atomic bomb. Some say that it has made war so terrible that mankind will shrink back in horror and wars will cease. But so it was said of the airplane and no doubt of gunpowder. But horror and dread do not deter men from war; and even though we fear that another war will destroy an already tottering civilization, we are preparing for future war.

There has been a great deal of thought in regard to the causes of war, but I believe that much of the philosophy that has supported modern war has its origin in biological thought. No concept has influenced more profoundly the thinking of the past century than that of evolution. Darwin's explanation of the origin of new forms of life was so thoroughly accepted that even though biologists have since repudiated much of it, as Darwin himself undoubtedly would have done, the man in the street is unknowingly a Darwinian. Darwin believed that changes sufficiently great to constitute a new species came about through the slow accumulation, often over a long period of time, of slight variations, preserved as the result of a struggle for existence, largely *within* the species. The Germans were especially committed to Darwinism. Some of their philosophers sought to justify war and the

creed of Nordic superiority by identifying war with the struggle for existence. Logically it became the duty of a superior race to impose its culture and philosophy upon other and inferior peoples. While in general we condemn this philosophy, we have been influenced by it to a greater extent than we are willing to admit. In the minds of the most of us, the world of life, including human life, is envisioned as "red in tooth and claw." Competition as a controlling force in life has come to be regarded as almost sacred and to be preserved at all costs.

So thoroughly have we accepted the idea of the necessity of competition that we have tended to lose sight of the fact than Darwin stressed the cooperative relationships existing between many forms of life, not only within species, but between species often genetically unrelated. Since Darwin's time, many more of these relationships have come to light. If we could analyze thoroughly any community of organisms, we would probably find as much cooperation as competition. The relation of mutual helpfulness, often called symbiosis, has many well-known examples, such as those existing between flowering plants and their pollinating insects; between the termite and its wood-digesting protozoa; between nitrogen-fixing bacteria and the legumious plants; between animals and the plants whose seeds they scatter.

These are obvious and direct relationships. Others may be less direct and more difficult to analyze. The soil contains a complex of organisms, influencing one another, as well as the plants whose roots penetrate the soil. The individuals of any community, such as a forest, are bound together by an intricate network of interrelationships, so that the community really becomes an organism. In a climax community, cooperation and competition are so balanced that the community may remain stable for ages.

Also, as Kropotkin[2] has pointed out, the bitterest phases of the struggle for existence are those involving the external inorganic environment. Drowning, freezing, starvation probably account for the major part of the deaths among lower organisms.

About the beginning of the present century, another natural-selection theory, the mutation-theory of DeVries, claimed the attention of scientists. DeVries showed that new species are formed not by the slow accumulation of recurring fluctuating variations, but suddenly, through the occurrence of mutations—new species, fully formed in one generation. The struggle for existence which ensues is a competition between the old species and the new. It is interspecific, not intraspecific. Within a species, the relationship of the individuals is cooperative, rather than competitive. In some groups of insects, as Wheeler and others have shown, cooperation is carried to the extreme.

Man is the only species of animal that spends a considerable portion of its energy in killing other members of the species. The chickens of a flock all peck and often kill the weakest member; pigs pursue and often destroy the "runts" of the herd; but this may serve to strengthen the hereditary quality of the group through the elimination

2. Kropotkin, P., *Mutual Aid, a Factor in Evolution.*

of the weak. But instances where members of a species array themselves in organized combat with others of the same species are rare. Man alone indulges in war.

It is not difficult to show that war does not accomplish the goal of the struggle for existence; that is, the survival of the fittest. In war, the bravest and most indealistic volunteer; the best, physically and mentally, are drafted. On the average, the weakest are reserved to propagate the next generation. The progressive deterioration of nations such as France, after a long succession of wars, has been demonstrated.

To summarize: I have tried in the folllowing ways to show that biology does not justify war:

1. Darwin emphasized cooperation as well as competition. Since Darwin's time the role of cooperation as a life-force has come to be more fully understood.
2. As Kropotkin early showed, the keenest phases of the struggle for existence are those involving a struggle with the external environment.
3. DeVries, in his mutation-theory showed that the fate of a species depends upon a struggle between species, rather than within a species.
4. War does not conform to the test for the struggle for existence, since it preserves the unfit, rather than the fit.

The role of cooperation (mutual aid) as a biological factor was discussed in 1880 by Kessler, the Russian zoologist, and greatly expanded in 1902 by Kropotkin[2]. Allee and his students have carried on an elaborthe program of research, seeking to analyze the interrelationships existing among aggregations of animals. They have shown the advantages that come to animals living in groups, rather than singly; the effects of overcrowding in large aggregations; the various orders of dominance and subordination that come to exist in an animal group. They believe that a social organization involving cooperation was not an emergence late in the evolutionary process, but a principle of life that has existed from the beginning. It is conceived that the initial establishment of life on the earth was successful only when a sufficient number of individuals appeared simultaneously to permit the operation of the principle of cooperation. It is their belief that the interrelationships existing among groups of men are not merely analogous to those among lower animals, but that they have actually developed from them.

In man the element of purposiveness often modifies his interrelationships in extent, direction or definiteness of goal. It is the existence of this element of purposiveness that has given rise to the hope that groups of men, properly informed and motivated, may gradually bring about a balance betwen the competitive and the cooperative elements within the group and that this balance may eventually spread throughout the whole of human society. In small groups a high degree of balance has often been attained. Kropotkin points out the harmony existing within primitive tribes. Small civilized communities are often quite harmonious. Switzerland, with its traditionally antagonistic German, French and Italian elements, has been a peaceful and successful nation. Small cooperative communities, such as New Harmony, have had many elements

of success. A modern organization successfully employing cooperation as a dynamic force in community life is the Cooperative Movement, beginning among some poor weavers in Rochdale, England, in 1844, and spreading through other countries, including the United States, but especially successful in the highly intelligent Scandinavian countries, where, attempting to supplement, rather than to displace the existing capitalistic system, it has remade the economic life of those countries.

But now we are beginning to wonder if we can depend upon this slow evolutionary process for the successful establishment of the principle of cooperation. The time-element has suddenly assumed such an importance that if war is to be overcome before civilization is destroyed, all the forces that tend to integrate human society, rather than to disintegrate it, must be mobilized. As D. Elton Trueblood says in "The Predicament of Modern Man," "We are engaged in a race with Catastrophe."

Unfortunately the sciences most effective in providing the machines for waging war are those that are most exact—that is, involving the greatest use of mathematics and embodying a great fund of exact knowledge; while those that must be employed if the cause and cure of war are to be discovered are least exact and have principles least understood, especially as they apply to larger social and political groups. The accuracy and efficiency of the engines of war have reached a development undreamed of a generation ago; but the causes of war are rooted in the minds and spirits of men and in deep-seated traditions of national and racial groups. Sociology, economics and political science, while calling themselves "sciences" are less exact than the least "scientific" of the natural sciences. Psychology is far from being an exact science, though it has made great progress. Religion, which should be a potent force, is too often dominated by superstition, tradition and dogma.

In earlier times war was accepted as a legitimate procedure for the attainment of national goals. Recently nearly all the civilized nations solemnly renounced war as an instrument of national policy; but this was followed by the worst war in history. National leaders, actuated by motives of political expediency, personal or national ambition, plunge the world into war, with no thought of seeking the counsel of experts in the social sciences, to say nothing of using the results of research in the natural sciences.

Dr. Lyman Chalkley, of the Office of Scientific Research and Development, in a recent article in *Science*[3] points out that "Although this (World War II) was a scientific war, neither scientists nor technologists were members of the top military or civil policy-making groups." If the decisions on public affairs were based upon painstaking scientific research, rather than prejudice, tradition or political expediency, political crises leading to war would often be avoided.

The indifference to science on the part of our federal government is exemplified in its attitude toward scientific conventions. Meetings em-

3. Chalkley, Lyman, Science, Technology and Public Policy; Science, **102**, No. 2647, Sept. 21, 1945.

phasizing entertainment, such as horse-races or athletic events secured ready permission to meet; but grave consideration was necessary before the Indiana Academy of Science was given such permission. Of the major powers, Russia seems to be supporting scientific research most heartily. Even during the war, when Russia was very hard-pressed, an elaborate program of research continued.

If biology has provided the key to the solution of interracial and international conflicts through the principle of cooperation, it is evident that the next step is the practical application of this prinicple to the present world-crisis. This will require the mobilization of the best philosophical and scientific thought. The development of the atomic bomb cost two and one-half billion dollars and the coordinated efforts of sixty-five thousand scientists and technicians, over a period of years. The elimination of war is a goal as full of promise for the future of mankind as any toward which he can strive. Shall we entrust the future of the race to politicians to whom diplomatic procedure, military strategy, political expedience or national aggrandizement are too often the bases of decision, or shall we pool the abilities of our best minds? Clemenceau said that war is too important a matter to be entrusted to soldiers. Similarly, international affairs are too important to be entrusted to politicians.

Some will say that the establishment of world unity is simple, that all that is needed is to implant in the hearts of men the principles of Christianity. But just what does this mean in this complicated modern world? Christians seem confused. Christian Americans have bombed Christian Germans. Obliterated Nagasaki was the center of Christianity in Japan. Some go to war believing that they are thereby advancing the cause of Christianity; others refuse for the sake of conscience.

We have made great progress in working out our individual relations to other individuals. Property rights are better established. Dueling is no longer respectable. Fundamental individual rights are guaranteed by law. But suddenly through the development of means of transportation and communication, we have been brought into direct contact with other races and nations. The principles that seemed to work in the old world of isolation do not seem to operate or we do not know how to apply them in the new and more complex situations. The world has suddenly become a neighborhood. We shall need all the wisdom we can get if it is to become a brotherhood. If the principle of cooperation is fundamental, how can it be applied on a world scale? Is war a human instinct so deep-rooted that it cannot be eliminated? Is there a "moral equivalent of war"? Can human nature be changed, or are we so bound by inherited tendencies that we are incapable of unity on a world-wide scale? What shall we do with atomic power? What kind of an educational system will fit men to live in the new world? How much autonomy must each nation relinquish in order to form a world-state? What shall be done about tariffs? What are the aims of human society. In short, what is worthy of our faith?

A recent editorial in the *New Republic* reads: "It is high time for us to concentrate our attention and our ingenuity on achieving as penetrating, as accurate, as cool and competent a body of knowledge about

how to choose our aims and how to effectuate them as we have hitherto devoted to the secrets of matter." Also, "Scientists are better trained to cooperate with one another on an international level than any other group."

Tennyson says in Locksley Hall, "Science moves but slowly, slowly, creeping on from point to point." But in the development of the atomic bomb, science moved with a speed and certainty that surprised even those who participated.

Science does not claim to be able alone to remake the world; but it does claim to have a unique method of searching for the truth, which, if used cooperatively by all constructive agencies, may yet prevent civilization from sinking into a new Dark Age. A "holiday for science" has been proposed, to allow other agencies to "catch up" with the progress of scientific technology; but what we need is not less science, but the application of the scientific method to the study of all human problems.

ANTHROPOLOGY

Chairman: J. C. HOUSEHOLDER, Indianapolis

Mr. Wm. B. Adams was elected chairman of the section for 1946.

The distribution of aboriginal bastioned stockades in North America. MARY FRANCES KELLY, Indiana University.—Certain of the pre-Columbian Indians had a very highly developed system of defensive warfare. One of the most important manifestations of this system was the bastion. A bastion is a walled outset from a fortification, placed in such a position that the defenders can keep up a cross-fire along the front of the main wall. It is easy to see of how much value a system of bastions at convenient bow-fire from each other would be to a fortification.

There appear to have been three main developments of the bastioned stockade. Several Algonkian and Iroquoian villages have been found to include bastioned stockades, and the Mandan and Hidatsa of the Upper Missouri River also included the bastion in their scheme of warfare. But we must look to the Southeastern Area before we find wide and concentrated distribution of the bastion.

This southeastern development appears to center in the state of Tennessee along the great river valleys. From there it extends as far north as Aztalan in Wisconsin, and the eastern and western limits are provided by those Algonkian, Iroquoian, and Mandan-Hidatsa bastions that I have mentioned before. The sites where bastions are found in the Southeastern States are predominately Middle Mississippian in culture development.

A Preliminary Report on Martin County

WILLIAM RICHARD ADAMS

At the present time under the employment of the Indiana Historical Bureau and the direction of Mr. Glenn Black, an archaeological survey is being made in Martin County. Since there is probability of dam construction which will flood White River Valley between Shoals and Williams, special attention has been given to this pool area.

White River is located in a deep meandering valley into which the larger tributary streams flow in flat valleys. The minor ravines descend from the irregular ridge-tops as steep U-shaped trenches in which bed rock is prominent. The flat valleys contrast with their steep rocky sides where vertical bluffs of massive sandstone are prevalent. Bluffs of from twenty to fifty feet are common and vertical ones one hundred feet or more in height occur. On the outsides of the meander curves of White River these bluffs are particularly prominent and precipitous.

The two northern townships of Martin County are closed to examination since they are within the Naval Ammunition Depot, although from reports of former inhabitants there is little of archaeological interest there. Lost River township in the southeast has several good sites in it, although work there is hampered by the roughness of the land. Little work has been done so far in the most southwestern township, but I think it will likely yield some very interesting sites. In the central five townships are located the majority of the 130 Martin County sites found thus far.

For the county in general, six shell mounds have been located while reports of three more are on hand. These range from forty to one hundred and fifty feet in diameter, and are on high bluffs, with two exceptions. One is located at the foot of a vertical cliff and may represent material thrown over from a hill-top camp, since I have a report of shells having been seen on top of this cliff. The other is on a low sand ridge extending into the old river bottom.

I have visited about half of the twenty-seven overhangs or rock shelters reported. Four overhangs yielded small quantities of pottery, three have hominy holes, and three show no indication of use.

Fourteen locations have been designated as village sites—either on the basis of pottery presence or quantity of material found. One site within the pool area is of special interest and might be worthy of exploration. Here White River in flooding has produced a washout close to the edge of a level tract of several acres, most of which would probably show habitation debris if tests were made. This is in pasture now and the owner prohibits digging. Many pottery sherds are found there mixed with quantities of every fine flint chips and animal bones. The artifacts found by the survey consisted mainly of about a dozen finely-made trianguloids and a small expanded base drill less than an inch long.

One other village of some size is located in the southern end of Martin County. It is situated on a flat-topped ridge a quarter mile

from White River and is perhaps one hundred feet above the river. This site is approximately three hundred yards long by one hundred yards wide. Contained in this area, more or less at the edge, are three or four concentrations where shell, bone, flint, and fire-cracked rock are in abundance, and which I think constitute refuse pits. No pottery has been found at this site, although for surface material this is one of the richest sites in the county.

With the exception of possibly one small earthen and one or two stone mounds, all reports of mounds in Martin County have been unproductive.

Several burial grounds have been reported, but only one offers any evidence. This is located at one end of a half-mile length of river bottom which shows continuous traces of occupation, and which is supposed to have been a favorite camping site during historic times. Here the flood of 1882 washed out skeletons, associated with sherds of clay pottery and iron kettles.

A section of Indian trail approximately one-half mile in length has been reported to me in the southeastern corner of the county, but not other traces of it have been located.

The remainder of the sites are simple campsites—small areas showing only slight amounts of camp debris—and are of no particular interest at this time.

We hope to be able to finish the survey this season, and although looking forward to interesting developments, it is likely that the pattern for Martin County will remain predominately at a campsite level.

The Cato Site—Pike County, Indiana

GLENN A. BLACK, Indiana Historical Society

In November of 1940, at the annual meeting of the Indiana Academy of Science, I read a paper entitled "Cultural Complexities of Southwestern Indiana" in which I mentioned the Cato Site. As the title of the paper implied, the problem of chronology in the pocket region of Indiana is complex and burdened by a great variety of cultural material representative of not only a long habitation period but by a variety of peoples as well. Materials are found here that are common elsewhere and fit into established patterns from which order and sequence have been established. In addition to these orderly manifestations there are others which may fit individual patterns but their associations are such as to inject a question into their relationships one with the other. In this respect the Cato Site is one of the most disquieting.

In 1940 little could be said about the site or the materials it had produced for the artifacts were in the hands of the persons who had recovered them and an opportunity for detailed study had not presented itself. Since then all, or almost all, of the objects from the site have become a part of the collections of the Indiana Historical Society.

With the artifacts came the all too meager data which had been kept by those who did the digging. The explorations were made during the winter of 1939-1940 by Revis Campbell, of Boonville, and Haskel Woolsey, of Coe, assisted by willing, perhaps too willing, visitors upon occasion.

The site is located in Section 28, Township 2 South, Range 8 West, two and one half miles west of the village of Coe on the Cato farm. It covers about an acre on the crest and north end of a ridge which projects northward into the bottoms formed by the junction of Lick Creek and the South Fork of the Patoka River. Although the site has been called a "mound" there is actually little to justify the term. At present its location is marked largely by a variation in soil color—the inhabited portion being much darker than the surrounding fields. Although materials characteristic of the Shell Mound complex are present in the collection, the site is not nearly so abundantly littered with shells as are most true shell mounds.

The collection acquired from Mr. Campbell consists of over nine hundred individual objects made up of bone, stone, shell, and clay materials. During the excavation notes were kept only in exceptional instances and they are often too limited to be of value. No photographs were taken of objects or burials *in situ* and since the site was not staked out prior to exploration there was little or no system to the digging operations.

In the paper previously referred to I stated that the Cato Site produced materials having a Hopewellian affinity. This statement was

based upon inspection of only a portion of the total accumulation of materials which had been taken from the site and which were then in custody of Mr. Campbell. After studying the entire collection I am willing to remake the same statement but will hastily add that the Hopewellian aspects of the material are dimmed and all but eliminated by a preponderance of items that are distinctly Adena in type.

When all of the collection is laid out upon tables for observation certain things stand out as indicators of more than one culture complex. These indicators are not only distinctive so far as this collection is concerned but they also constitute diagnostic traits for the individual culture complexes which might be represented at this site. It is, to say the least, somewhat disconcerting to see, reposing side by side, an antler "atlatl hook" and a limestone tubular pipe of specialized form. Or, a typical Adena gorget next to a bannerstone of the "atlatl weight" type.

Taken as a whole the collection is made up of materials usually associated with Shell Mound sites. The "atlatl hook," "atlatl weights," engraved bone pins, engraved bone beads, large projectile points made of antler, spatulate forms of bone, cylindrical pestles, beads of shell and bone, and antler shaft straighteners or wrenches.

Almost as conspicuous as the Shell Mound traits are those which serve to mark Adena. These are, first of all, a tubular pipe so perfectly Adena that it might well have been taken from any one of the type mounds of Ohio or eastern Indiana. Quatra-concave stone gorgets drilled in the usual Adena manner—from one side only. A sandstone tablet having upon each flat surface a broad shallow groove, cache discs of Harrison County flint, disc shell beads, and antler handles.

There are several items which induced me to say, in 1940, that Hopewellian was involved. These are a cut mandible, a long copper awl still inserted in its original bone handle, drilled canine teeth in large numbers, and large flint blades carefully chipped and deeply notched at the corners. In addition to these items, which are in the collection, there is an outstanding object which came from the site but which has not yet been acquired. This is a small limestone bowl, beaker shaped, having a vertical rope-like decoration carved three times upon the outer surface. Such bowls are not common in any complex but this specimen is reminiscent of Hopewellian more than any other Ohio Valley culture.

There are many objects which are always difficult to allocate specifically to any complex. Such things as bone awls, small notched points, grooved axes, scrapers, drills, antler drifts, and slate pendants might logically be a part of any one of the complexes previously named or of still a fourth—Woodlands.

To bring some order out of this chaotic situation it was necessary to group the objects according to their known association in the few instances where that was possible. Data were kept on a few of the graves encountered and the material taken from these can be properly grouped together. When this was done it became evident that many of the items which would otherwise be difficult to place in their proper category resolve themselves into well ordered patterns. It also became evident that there was a definite tendency toward grouping of items having cultural

homogeneity as would be expected. Further than this, as trait tables were prepared and handled statistically, some of the items which were considered as being representative of Hopewellian are perhaps Adena in affinity. As an example, the copper awl in the bone handle might reasonably be assumed to be Hopewellian but when it is noted that it came from the same grave which contained the sandstone tablet wiht shallow grooves then the two must belong in the same complex and in this instance that would seem to be Adena.

We might take the antler handle as another example. This type of object is found in both Shell Mound and Adena assemblages and when found alone on a site some doubt would naturally exist as to which it might be diagnostic of. But when a handle is found in the same grave with two quatra-concave gorgets, each drilled in the proper manner, then there can be little doubt but that the handle is also Adena. It would have been pleasant to be able to report that the tubular pipe, which is so typical of Adena, was found with the same burial that produced the "atlatl weight" bannerstone, or, that an engraved bone pin of Shell Mound type was found with one of the Adena gorgets, but such pleasantries are rare in archaeology and this case is no exception.

A table was prepared using only those objects as traits which were found with burials and which, therefore, could be properly associated together. Columns were set up in which each trait could be allocated for Adena, Hopewellian, Shell Mound and Lamoka Lake Site which is Ritchie's type station for the "Archaic" period in New York.

This table showed that 31 traits could be Adena, 8 traits Hopewellian, 40 traits Shell Mound, and 20 traits Lamoka. The case for a Hopewellian affinity becomes very weak when we note that there are only 8 traits which are most apt to represent that complex alone. As a matter of fact there are only two traits in the list which stand out for Hopewellian. These are the cut mandible and canine teeth drilled through from one side of the root to the nerve channel only. The limestone bowl which was referred to above was not included because it is not now a part of the collection.

There are 14 trait occurrences which might be either Adena or Shell Mound or both; 9 which might represent either Adena or Lamoka and 17 which might be either Shell Mound or Lamoka.

Not much satisfaction can be derived from a table of traits which is so inconclusive as this one. The site could hardly be representative of all three, or four, complexes. The question naturally comes up, therefore, that if this trait occurrence table is unsatisfactory and contains traits which could be representative of any or all of the possible complexs involved, what can be done about it?

There are certain items in this collection which I consider to be fundamental, or basic, and to be representative of one complex alone. As an example I would cite the tubular pipe of stone, having parallel sides, a specialized mouthpiece and bi-diameter drilling for the stem and bowl openings. This type of object is not only Adena but I believe it to be early Adena and wherever found should serve to mark that site, or burial, as Adena or at least Adena influenced. Such being so it would

seem to follow that if a burial is found, and with it a tubular pipe of this type, then that burial is Adena and those other objects which might be in association with the pipe and burial are also Adena. If such reasoning is sound, and I believe that it is, it justified the preparation of another table and grouping of those trait occurrences which can be associated without doubt. When this was done many of those traits which previously showed up as questionable markers for one or the other complex are properly and amply taken care of.

The same proceedure was applied to those traits for the Shell Mound complex. As an example, all those objects found with a burial that had with it an "atlatl weight" bannerstone were considered as forming a part of the Shell Mound assemblage.

Such a table was prepared and analyzed with interesting results. Twenty eight trait occurrences were assigned to Adena, 12 to Shell Mound and Hopewellian and Lamoka were completely elminated—each with a perfect zero.

The question of possible cultural stratigraphy within the site can be raised at this point for such a condition certainly is suggested by the figures cited above. The site may have been stratified but the methods used in the exploration were not of a nature to reveal it. The notes with the collection do not help out in this respect. It would seem, though, that stratigraphy is not the answer for there are instances in the last mentioned trait table of cross-overs of traits from one complex to the other. Examples indicate that the long antler projectile point was found in association with Adena material as well as Shell Mound material. The same is true for the cylindrical pestle and the bone spatulate tool made from the tibia of deer or elk. These items would not normally be considered as typical of Adena but when they are found with Adena material they should be so accepted.

This second table leads me to conclude that at the Cato Site we have either a late Shell Mound or early Adena occupation. That it is late Shell Mound would be suggested by the presence of small projectile points of stone and pottery. That it is early Adena is suggested to me by the presence of the tubular pipe, gorgets of stone, antler handles, and the association of these things with materials representative of the Shell Mound complex which, everywhere in the Ohio Valley underlies chronologically all other complexes. The minimum amount of shells evident at the site might reasonably indicate a drift away from a shell gathering mode of existence toward a fuller life.

Those traits which seemed too indefinite to limit them to any one complex, unless association so placed them, are probably Woodland traits and this suggestion is strengthened by a consideration of the pottery from the site, even though no sherds or bowls were reported with burials. This pottery is of two general types. The first, and oldest, is a coarse, thick, granular tempered ware having either a plain, cord marked or fabric impressed surface. Some of the sherds of this type have crushed flint as the tempering medium. The other type is also granular tempered, but is thinner walled with smaller granules mixed with the paste. It is cord marked and no fabric impressions appear on any of it. These

two pottery types are Woodlands and examples of both are produced by the oldest pottery bearing sites now known in southwestern Indiana.

Summarizing it seems to me that, in the Cato material, there is good evidence of an early Adena occupation. Evidence is suggestive of a people emerging from a Shell Mound culture into something more elaborate and based upon change in subsistence. It also seems clear that, whether the material be called late Shell Mound or early Adena matters not nearly so much as that it must be considered as representative of a transitional folk. These things, to me, seem obvious—more so than in any other site of which I am aware. It seems that both the late Shell Mound people and early Adena people were using large flint and antler points, the antler handle and even the atlatl, or spear thrower. The objection might be raised that Adena is primarily a mound building culture and that no mound was evident at Cato. This is probably true but it is equally true that Adena people need not always have built mounds. This may be one of those rare instances of a habitation site of this group—one not covered by a mound or completely eradicated by the process of mound erection as has happened so many times upon sites of this people.

Southwestern Indiana still has its "cultural complexities" not the least of which is this one. Perhaps I have worked too hard in an attempt to salvage something from this invaluable collection. If so I stand corrected, but material is of little value unless it is used and in this instance I believe the material speaks for itself.

Virginia's Indian Neighbors in 1712

J. C. HOUSEHOLDER, Indiana Historical Society

Colonel Alexander Spotswood (1676-1740) arrived in Virginia in June of 1710, the Deputy, or Lieutenant, to George Hamilton, Earl of Orkney, the British government's official, but never resident, Governor and Commander-in-Chief of the Colony of Virginia. Spotswood (1) was very much a governor in every sense of the word, and developed into very much of an American, the type of American that broke with parent England in The Revolutionary War. After his governorship was cancelled in 1722 he spent the rest of his days in Virginia until his death in 1740; and in Virginia his children established or married into powerful families that played important roles of leadership in the late colonial and early continental periods of the State's history.

When Spotswood took over the affairs of the Colony its people were in a relatively tranquil social and political frame of mind both internally and externally, but both domestic and foreign economies were anything but prosperous. Spotswood did much to set in motion the wheels of agrarian production plus the beginnings of a manufacturing economy, at the same time regulating taxes and government supervision, to the end that for the first time in her hectic history Virginia began to build the sterling character that was developed into the flower of England's colonial possessions by the early 1770's. Also, Spotswood was a splendid military leader and a real Indian fighter; but there were few Indians to fight in Virginia.

Among the many subjects under discussion in his lengthy letter, dated from Virginia, July 26, 1712, to the Council of Trade, London, Spotswood wrote the following interesting paragraphs about the Colony's Indian neighbors:

> "Concerning the Strength of our Neighbors, I suppose to be meant of the Neighboring Indians (for there are no other foreign Nations near this Colony), in answer to which there are nine Nations of Indians Tributary to this Government, Vizt: The Pamunkys, Chickahominys, Nansemunds, Nottoways, Maherins, Sapons, Stukanocks, Occoneechees and Totteros, whose number of men, women and children do not exceed 700 in all, and of these there may be reckoned 250 fighting men. These are all in an Entire Subjection to this Government and live quietly on our Frontiers trafficking with Inhabitants their Skins and Furs for Clothing, Powder, Shot and other European manufactures. The next Nation of Indians with whom we have had frequent correspondence and who are most like to annoy us is the Tuscarurs, said to be about 2,000 fighting men. They live within the bounds of Carolina, and before the late Massacre, committed there by some of them and others, had a constant Trade with our Inhabitants for the like Commiditys as our Indians, but since that time I have prohibited all Commerce with them till they give satisfaction for the murders committed in Carolina. Besides these We have no other Nations that frequent our frontiers, and those with whom our Traders have ye Chiefest Traffique for Skins live

some 4 or 500 miles to the So. West of us and their names scarce known to any but the Traders." (2)

Spotswood's Indian problems were not, of course, either so simple or so rosy as his letter may have suggested to the Council of Trade, in London; but the fact remains that of the great Powhatan confederacy of Algonquian tribes in Virginia when the Jamestown colonists arrived, only a few poor tribal remnants remained in 1712. Of the Iroquoian Tuscarora whom his letter says "are most like to annoy us," within the year this letter was written, the Tuscarora, together with kindred Iroquoian tribes, the Meherrin and Nottoway and the Siouan Tutelo and Saponi tribes, were gathered together at Fort Christian, Virginia, and in the same year (1712) were started on their slow journey northward through the Susquehanna Valley until they finally reached the Iroquoian Five Nations tribes in New York State, by whom they were adopted. (3) This relieved the Virginians of the onerous proximity of their Carolina Indian neighbors and four of their nine immediate and tributary Virginia neighbors.

Spotswood still was faced with the task of protecting his western frontiers from the Five Nations Iroquois, particularly the Seneca, during their continual raids against the Siouan Catawba in South Carolina. He finally solved this problem by establishing compact communities of friendly Indians powerful enough to resist the Iroquois. This culminated in his treaty with the Iroquois by the terms of which they were to stay north of the Potomac river and west of the Blue Ridge Mountains. As for "ye Cattabaw and several other Southern Nations of Indians" two children from each Indian town, sons of their great men, should be delivered as hostages to Virginia, and educated at the Indians' expense at Fort Christian, Virginia. (4) During the frightful Yamasee war in 1715, in which this Muskhogean tribe lead an organized combination of most of the tribes below Charleston to the Florida border against the English, he successfully protected Virginia against the unrest this war created among the Indians closer to his frontiers.

The Governor foresaw serious difficulties with the Spaniards in Florida, and to settle them with vigor and dispatch advocated to the British government the seizure of Florida. Likewise he raised a powerful voice on behalf of English interest west of the Alleghanies, and to this end suggested to London the establishment of a chain of forts from the eastern Great Lakes to the Mississippi river as a bulwark against the French. Spotswood splendidly typified the spirit of the English colonists. They were empire builders. The Indians had little chance against them. At the first opportunity the Red Men were disposed of. True, William Penn did his part in a rather polite manner, but the English from Maine to Georgia came to build an English civilization, and the Indians were to have no part in it. The same thing happened when the post Revolutionary Americans crossed the mountains into the Ohio and Mississippi valleys. The French, on the other hand, were willing to temporize and compromise with the Indians. They were ready and willing to live with them, and to share the Indian formula of culture so long as the fur trade and its enormous profits lasted. The Spaniards were

nothing more nor less than plunderers and murders. The English were empire builders, the French adventurers, the Spanish destroyers. The fate of the American Indian was a hard fate.

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3. Weer, Paul, 1937. Preliminary notes on the Iroquoian family, Indiana Historical Society, Prehistory Research Series, Vol. 1, No. 1 (Indianapolis) pp. 8-9.

4. Official Letters, op. cit., Vol. 2, p. 147.

On the Physical Types of the Shoshonean-Speaking Tribes

GEORG NEUMANN, Indiana University

The racial history of the Indian tribes of the so-called Shoshonean linguistic area is one of the least known of the continent. This is reflected by the paucity of published data from this vast area, which extends from the northern part of the Great Basin to the coast of southern California. Like most other areas this one has had a complex history despite the fact that the cultures found in it are as a whole relatively simple. This has not been brought out in connection with the published data on skeletal material from this area, and for this reason needs clarification.

When Hrdlicka published the second section of his *Catalogue of Human Crania*,[1] he included a section dealing with the skulls of Shoshonean tribes, and on the basis of a series of twenty-six male and fourteen female skulls from this area postulated a Shoshonean type. Having excluded the crania of individuals of Shoshonean-speaking tribes of southern California and Hopi crania, he then describes this type (p. 101) as follows:

1. The tribes of this group, as far as represented, show a fairly uniform type.
2. This type is characterized by—
   Mesocephaly;
   Low to medium height of the vault;
   Medium face, orbits, and nose.
3. The type is not far from the Algonkin, but differs from this by a perceptibly lower vault.

Further on, after describing the crania of California tribes (p. 127), we find the statement that this type appears to be practically identical with that of the Shoshoneans. A Shoshonean-Californian type is thereby established, which, however, still excludes the Hopi, who are considered with Pueblo groups of the Southwest.

Next we may consider the linguistic basis for such a grouping, and whether it is affected by the extension of the stock. Since the establishment of the physical type, the evidence of comparative linguistics has shown that the Shoshonean grouping on the order of a stock must be abandoned. A more inclusive category, Uto-Aztecan has taken its place, including such languages as Luiseño, Cahuilla, Serrano, Tübatulabal, Pima-Papago, Hopi, Ute-Southern Paiute-Chemehuevi-Kawaiisu, Shoshoni-Comanche-Gosiute-Wind River-Panamint, Mono-Bannock-Snake-Northern Paiute, and Nahuatl. Hyphenated names indicate a single

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[1] Hrdlicka, Ales. Catalogue of Human Crania in the United States National Museum Collections. The Algonkin and Related Iroquois; Siouan, Caddoan, Salish and Sahaptin, Shoshonean and Californian Indians. Proceedings of the United States National Museum, 69, 92-101, Washington, D.C., 1927.

language; intermediate groupings, that is, the grouping together of a number of these languages within the stock, have not been made as yet. In other words, Luiseño and Tübatulabal of southern California may be less closely related to each other than Tübatulabal to Nahuatl. Formerly Luiseño and Tübatulabal were grouped together as Shoshonean, while Nahuatl was considered a language of a separate linguistic stock—Nahuatlan.[2]

At first glance it would appear that there should not be any fundamental objections from the physical side to this extension, thus making a linguistic stock and physical variety almost coterminous, especially since races of an older dolichocranial stratum are to be found along the western side of the continent from British Columbia to Central America. In fact, von Eickstedt[3] suggests such a grouping under the name Margid race. One would soon find, however, that such wide pooling of material would be of little use in detailed historical reconstruction of the relationships and movements of prehistoric groups of this region. Practically all differences would disappear in non-existent averages which would be meaningless in wider comparisons with the Fuegid and Lagid varieties of South America. To the north within the Shoshonean area, Sylvid admixture is found extending to the Pacific coast. This is swamped by a later overwash of the southward expanding Pacifids,[4] giving rise to the Prairids to the east, and sending offshoots such as the Apache and Navaho far to the south. This Pacifid expansion also makes itself felt in northern California—a fact that is ignored by Hrdlicka in classifying all California crania into a single type—and appears as a hybrid type among northern Shoshoneans. Older Centralid elements were evidently swept along by the Pacifids, later to become settled in central California, and as Hopis in Arizona. The oldest element, represented by the California Mission Indians, differs widely from the Centralids and Pacifids and may not be too closely related to the Pima, Papago, and extinct tribes of Lower California. In Mexico the originally Margid Aztecs, whose closest relatives may have been the Tarascans from a racial point of view, became extensively mixed with Centralid Toltecs. Thus through various contacts with surviving older groups or expanding later ones, each tribe has a little different racial history which has to be examined individually in the light of archaeological data. It follows from this that the application of a linguistic name—Shoshonean—to a variety of Man would be misleading, and Hrdlicka's median values for nearly all averages suggest a too inclusive nature of his grouping. Until more is known of the composition and relationships of this larger group, I would retain for it the term Margid variety, an appelation that has no linguistic or cultural connotations.

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[2] Thomas, Cyrus and John R. Swanton. Indian Languages of Mexico and Central America and Their Geographical Distribution. Bureau of American Ethnology, Bulletin 44, Washington, D.C., 1911.

[3] Von Eickstedt, Egon. *Rassenkunde und Rassengeschichte der Menschheit,* Stuttgart: F. Enke Verlag, 1934, p. 709.

[4] *Ibid.*

Lastly I would like to indicate in a few words how the prehistoric skeletal material from Catlow Cave No. 1 fits into the above sequence of types. This cave in which Cressman[5] discovered a skull which promises to be of some antiquity is located in Harney County, Oregon, and hence in the northernmost part of the Shoshonean area. For this reason Cressman as well as Hrdlicka, to whom the skull was submitted for description, compared the specimen with known Shoshonean ones.

In this report Hrdlicka did not use the term Shoshonean type but substituted "oblong-headed West Coast strain." Hooton, to whom the skull was submitted for study later, in general concurs in that he identifies it as being of the Basket-Maker type of the Southwest. At the end of the report Cressman gives a table of measurements of adult male "Shoshonean" crania from the U. S. National Museum collections. These already represent a number of varieties: Piegan and Blackfeet which probably are predominantly Sylvid; Steins Mountain, which may be Pacifid, Centralid, or Prairid; and the rest probably predominantly Margid. The exact identification as to variety of the Steins Mountain skull and a series from Blitzen valley, Oregon, which is also appended to the report, is not possible as neither height measurements[6] nor morphological attributes are listed. Nevertheless, despite of the heterogeneous nature of the U. S. National Museum series there are enough Margid skulls among them to indicate the difference between Margids and such a series as that from Blitzen Valley. This difference is of about the same order as that between the skull from Catlow Cave No. 1 and the Blitzen Valley series—a divergence which Cressman notes in his comments.

[5] Cressman, L. S. Archaeological Researches in the Northern Great Basin. Carnegie Institution of Washington, Publication 538, Washington, D.C., 1942, 141-143.

[6] Neumann, Georg. American Indian Crania with Low Vaults. Human Biology, 14, 178-191 (1942).

Passamaquoddy and Quapaw Mnemonic Records

PAUL WEER, Indiana Historical Society

The records of the preliterate American Indians were transmitted from generation to generation by word of mouth by a group of elder record keepers who, at the same time, instructed certain qualified young men of the new generation to carry on after them. This was accomplished by committing to memory the national or tribal chronicles: history, legend, and folklore; but, to assist the memory, systems of mnemonic devices were often invented. The Walam Olum of the Lenape represents this practice carried to the highest point of accomplishment. The two cognate examples cited here do not have the historical depth nor the breath-taking sweep of historical continuity found in the Walam Olum. Nevertheless they do add to our present accumulation of knowledge some additional information concerning this Indian method of continuing through the present and into the future the history of the past.

The Walam Olum, or Painted Record, of the Lenape is the most outstanding attempt of preliterate Indian tribes of the United States to document their past, so far known to have been preserved. In addition, the record has a most interesting history, since its discovery. The mnemonic sticks are reported to have been found among the Lenape (Delaware) Indians living along White river, in Indiana, in the year 1820. The words relating to them, written in mixed modern and ancient Lenape probably by an (European) educated Lenape chief or a keeper of the records, were obtained in Kentucky in 1822. Both sets of material were acquired by Constantine Samuel Rafinesque during his Kentucky residence (1819-1826); and, fortunately, were included in the small portion of his collections he was able to take with him when he left Kentucky in the latter year and returned to Philadelphia to spend the rest of his days. With the aid of dictionaries prepared by David Zeisberger and John Heckewelder, famous Moravian missionaries to the Lenape, Rafinesque finished his translations in the year 1833, and published his texts in 1836, "*American Nations*" (Philadelphia).

Fifty years later, Daniel G. Brinton, in his "*Lenape and Their Legends*" (Philadelphia, 1885), brought to light the Rafinesque treatise, and after a long thorough reexamination, under the advantages of his own scholarly qualifications for such a task, confirmed the elder scholar's conclusion that the Walam Olum was a genuine Indian creation of great value.

Brinton deposited the original Rafinesque manuscript, carrying drawings of the pictographs and the written words, in the University Museum, at Philadelphia; and left to future generations this suggestion: The Walam Olum "will repay more study in the future." Now, sixty years after Brinton, this obligation is being undertaken by the Indiana Historical Society, because, first, the Lenape "Painted Record" is part of

Indiana's heritage from her native inhabitants of the long ago; and, second, the establishment of the authenticity of the record and its detailed collation with present known data will throw a flood of new light upon the prehistory of America. The Walam Olum is in fact a great chronicle of the Lenape nation from its earliest ancestral Algonquian days. Beginning before the Lenape themselves had become differentiated from the parent body, the five songs recite the story of creation, give the flood legend, report the crossing of Bering Strait from Asia to America, and continue through two lengthy songs to recite the story of their conquests and cultural growth as they travel, for generation after generation, across the American continent until the Lenape proper establish themselves in "Sassafras Land" on the banks of the river Delaware where they were found by William Penn in 1682, and by the Swedes and the Dutch and the Virginian John Smith earlier in the same century, and probably by Verrazano in 1524.

The Passamaquoddy mnemonic records (1) were created by the combinations of various colored wampum beads arranged in long strings thereof. These strings were obtained by Dr. J. Dyneley Prince, at Bar Harbor, Maine, in the year 1887, from a Passamaquoddy Indian, Louis Mitchell, who was at that time an Indian member of the Maine legislature.* With the strings Mitchell gave Prince the Passamaquoddy text written syllabically without arranged divisions into words, sentences or paragraphs, and a translation of the text into English. The records deal first with the formation of a league of peace; and then continue not as history, but as the prescribed ceremonials to be instituted at the death of a chief; the ceremonies of electing and installing a new chief; the ancient rites of the marriage ceremony; and, lastly, the marriage ceremony in later days. There is apparent continuity in the records, for they begin with the peace treaty and continue thereafter with the "Wampum Laws" which, at least theoretically, were written as part of the treaty. Without doubt there were many more Passamaquoddy "Wampum Laws" than the few obtained by Prince in 1887. The story of the peace treaty is divided into two "Wigwams." When the delegations are finally assembled, for the first seven days a great silence is observed by all the participants, that they may meditate on their speeches. This is called the "Wigwam of Silence." The period of speech making is the "Wigwam of Oratory."

The Passamaquoddy belonged to the northeastern group of Algonquian tribes known collectively as the Wabanaki. When first found by the whites the Passamaquoddy lived on Passamaquoddy bay and along the St. Croix river on the boundary between Maine and New Brunswick. The Wabanaki included, to the west of the Passamaquoddy in order, the Malecite, the Penobscot, the Wawenock, and the St. Francis Abenaki (formerly the Norridgewock, Aroosaguntacook, Sokiki, and other remnants). To the east of them, marginal but still belonging to the Waba-

* The Passamaquoddy and Penobscot tribes were permitted to send a representative to the Maine legislature to speak only on affairs connected with the Indian reservations in that State.

naki group, were the Micmacs (2). All of these tribes possessed a similar simple hunter-fisher Northern Algonquian culture, diminishing in complexity from west to east (3). The Wabanaki lived, literally speaking, in perpetual war with the Iroquois to their west. The Wabanaki were more than the fighting equals of their enemies, and were more annoyed than frightened by them. Consequently, after generations of indicisive wars with the Wabanaki, the Iroquois tried to bring them into their league. The Wabanaki had a loose federation among themselves, and therefore were not altogether unprepared to consider a proposition of larger scope. Finally, about 1700, the Wabanaki tribes, more through good judgment than fear of their enemies, ceased hostilities; and the Passamaquoddy, Penobscot, Malecite, and Micmac sent delegations to the Iroquois and entered into a more or less permanent league relationship with them (4). This was consummated at the great peace treaty at Caughnawaga. As the translated wampum text reads: "The father ruling the wigwam was the Great Chief who lived at Caughnawaga." (5) Therefore, the wampum mnemonic records reciting the preliminary steps of calling the delegates, their assembly, and on through the "Wigwam of Oratory" with which the league covenant is concluded, can be dated about 1700. Moorehead found wampum in Indian graves in Maine. Dating the other "strings" which relate to ceremonial practices would, conceivably, suggest a linguistic problem. The "string" describing "The marriage in later days" obviously is of late historic origin.

The Quapaw record is less authentic, one may well say apocryphal. On the authority of a Dr. J. L. LaRue (6), Belva, Arkansas, Mr. Higgins, an English mining engineer, "found secreted in a cleft of the rocks on the northwest angle of the Pilot Mountain, located in Scott County, Arkansas, 212 slate tablets, with three pictures on each side. There were 1,272 pictures in all. . . . The pictures portray a history of the Quapaw Indians during the reign of Queen Singing Bird the First, or the good queen, as she was called by the Indians." (7) Concerning the slate pieces it seems that Mr. Higgins shipped them to England and received in return for them the sum of two thousand dollars. Shortly thereafter Higgins was found dead, and was buried near Sugar Grove, Logan County, Arkansas. But before this tragic exit Dr. LaRue was permitted to copy the pictures.

We will now quote the good doctor, for no one else could possibly give the subject equal glamor: (8)

> "I cannot give you the dates; but it was before the introduction of fire arms. It tells of the massacre of the Spanish miners, and gives a graphic account of the bloody battle fought between the Quapaws and Chickasaws, near where the city of Little Rock now stands. The Chickasaws were defeated and driven back east of the Father of Waters. Also the appointment of the gifted young chieftain, Silent Tongue, to the office of ambassador to frame a treaty of peace with the Chickasaws. Gives an account of his journey, his friendly reception, the ceremony of burying the tomahawks, and the speeches made on the occasion. It gives the manners and customs of the Quapaws, their religion, and form of marriage. There were two tribes of Indians incorporated in one nation, and ruled over by the Sun Chiefs. Their government was constitutional monarchy. The legislative body was composed of a house of warriors,

> and a house of chiefs. . . . There is history, religion, romance, manners, customs, ceremonies, speeches, and an account of a trial before the queen."

The Quapaw were a tribe of the Siouan language family, and according to their own traditions once lived in southwestern Indiana along the Ohio river near the mouth of the Wabash. There is no reason to believe that they could not have developed a mnemonic system for the keeping of records. So far as the fanciful tale reported here is concerned, the writer of this paper wrote to the Society in whose early volume it was published with other Indian items under the title "Aboriginal and Indian Remains." The present officers of the Society know nothing about the facts pablished in the aricle on the subject of the Quapaw record. If the record was genuine in any respect whatsoever, it was, of course, of modern origin as the subject matter clearly indicates. It might be the modern survival of an ancient Quapaw mnemonic system now long since lost and forgotten.

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8. *Ibid.,* p. 276.

BACTERIOLOGY

Chairman: C. M. PALMER, Butler University

The BACTERIOLOGY SECTION met with the Indiana Branch, SOCIETY OF AMERICAN BACTERIOLOGISTS.

Mr. F. A. Miller, Eli Lilly and Co., was elected chairman of the section for 1946.

Some of the factors influencing death from gas gangrene. VERSA V. COLE, H. R. HULPIEU, and L. A. WEED, Indiana University.—The factors in death from gas gangrene which have been recently investigated are: total carbon dioxide content of blood, blood sugar, temperature of the infected region, and narcosis of the animal. None of these have shown an effect on death rate. All except the blood sugar seemed to exert some effect on survival time. Infection with Clostridium welchii lowered the carbon dioxide content of the blood up to death. However, those dogs which had a high normal carbon dioxide content had a shorter survival than those which had a low normal carbon dioxide content. Blood sugars at death were usually low. The survival time was increased by narcosis and was further increased by cooling the infected region.

A dichotomous key to the species of the genus bacillus. C. M. PALMER, Butler University.—A key to the species of the genus Bacillus has been formulated which is dichotomous and more complete than the types such as are presented in Bergey's Manual of Determinative Bacteriology. Nine groups of species are first distinguished and keys to the species in each group (excepting the thermophilic) have been constructed. Care has been taken to use clearly recognizable distinctions throughout the key.

Influenza virus vaccine for general use. H. M. POWELL, Lilly Research Laboratories, Indianapolis, Indiana.—Experimental evidence is presented that influenza virus vaccine, types A and B, can be prepared on a large scale with much greater yield than similar vaccine for military use has shown heretofore. This may make this vaccine practicable for general use, provided the actual results in prevention of influenza are finally satisfactory.

Greater yield is obtained by using more than the customary one-tenth volume of saline in eluting the virus following its adsorption on red blood cells during the process of purification of the raw virus-containing periembryonic chick embryo fluids. Resultant vaccine when given in two weekly doses of 0.1 cc each to Swiss mice immunizes against 10,000 LD 50 of active type A mouse lung viruses, and when given in two weekly doses of 0.001 cc each to Swiss mice immunizes against 1,000 LD 50 of active type B mouse lung virus.

An Agar Decomposing Organism Isolated from Soil

F. JOSEPH MURRAY, Purdue University

A complex carbohydrate, agar is attacked by very few organisms and in text books published as recently as 1900 we find the statement that agar is not liquefied by any organism. Since that time a few agar decomposing organisms have been reported in the literature, the first being a species isolated from sea water and described by Gran in 1902. This organism, which has been named *Bacillus gelaticus*, (1) occurs in three varieties distinguished by chromogenesis and requires a high salt concentration when grown on artificial media. In 1905 Panek reported an acid producing rod which had the ability to liquefy agar and this is now known as *Bacterium betae viscosum*. Biernacki in 1911 isolated an agar decomposer from raisins and this organism, also an acid producing rod, was named *Bacterium nenckii.* (2) Perhaps the best known of the agar decomposers on record is that reported by Gray and Chalmers in 1924, a cellulose decomposer, this organism is known as *Microspira agar-liquefaciens* (3). The most recent report of such an organism is that of Stanier, (5) his description of *Actinomyces coelicolor* having appeared in 1942.

Attention was drawn to the organism here reported during experiments on cellulose digestion by soil organisms from the grounds at Purdue University. Active digestion of cellulose was observed in an aerated flask and plates were made in an attempt to isolate the cellulose-attacking organisms. The medium used was one reported by Dubos (4) as favorable for the growth of cellulose digesters and consisted of the following:

Na NO_3	0.50 gms.
Ka HPO_4	1.00 gms.
Mg $SO_4 \cdot 7H_2O$	0.50 gms.
K Cl	0.50 gms.
Fe $SO_4 \cdot 7H_2O$	0.01 gms.
Distilled water to 1000 ml.	

To the basal medium, agar was added to give a concentration of 1.5 per cent and filter-sterilized glucose was added directly to the plates in a concentration of 0.1 per cent. These plates were observed to contain many definite depressions with small yellowish deep colonies occupying the center of each and every depression. Since it was a mixed culture, there were many other organisms growing on the surface and isolation presented a problem. Various media were tried and while growth of the organism took place on many of these, the phenomenon of agar digestion was most satisfactorily observed on the original Dubos medium plus a 1.5 per cent concentration of agar. However a pure culture was obtained from surface colonies appearing on a medium en-

riched with a nutrient substantially the same as corn steep liquor, streaks from these colonies giving rise to the depressions on Dubos medium.

Platings of the organism give rise to yellow and white colonies with the white predominating. These colonies in turn are capable of giving rise to more yellow and white colonies both types resulting from either a yellow or white colony. Microscopically, stains of organisms from both colonies present a similar picture in that both are gram negative, non spore forming rods measuring 0.5 μ by 2.0 μ and possessing true motility. Stains from the yellow colonies, however, reveal some spindle-shape cells and it is thought possible that the difference in color is related to an age factor.

The organism fails to ferment carbohydrates with the production of acid and gas, nor does it attack cellulose. Mesophilic with an optimum temperature of 30°C, the organism is aerobic to microaerophilic and grows readily on potato with a characteristic yellow pigment. Litmus milk is reduced after two days, while indole, Voges-Proskauer, and methyl red tests are all negative and there is no reduction of nitrates.

There were no evidences of liquefaction around the depressions and a test devised by Gran making use of an iodine-potassium iodide solution failed to demonstrate liquefaction.

Varying the concentration of glucose disclosed that higher levels such as 2 per cent resulted in increasing amounts of growth, but the degree of decomposition is far less at this concentration than at the 0.1 per cent level.

It was found that growth of the organism depends upon the method of sterilizing the glucose, normal growth taking place when the glucose is filter sterilized and growth being inhibited to a very great degree with autoclaved glucose. Stanier has reported similar results with organisms of the cytophoga group and he explains it as a toxic effect of caramelization products even though the glucose is separately autoclaved in pure distilled water. This explanation seems the most satisfactory at this time.

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1. Bergey et al., 1939 Manual of Determinative Bacteriology, 5th edition, 138.
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3. *Idem, ibid.,* 111-12.
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BOTANY

Chairman: R. E. GIRTON, Purdue University

Professor J. E. Potzger, Butler University, was elected chairman of the section for 1946.

The growth of Oenothera plants from embryos cultured in vitro. RALPH E. CLELAND and MARGARET NEWCOMB, Indiana University.—Notable progress has been made in recent years in the cytogenetic analysis of Oenothera and in the application of cytogenetic methods in the study of phylogenetic relationships. This work has been largely confined, however, to the subgenus *Onagra (Euoenothera).* It is highly desirable to analyze other subgenera and to bring them into the same system with *Onagra,* thus gaining an understanding of the larger relationships existent in the genus.

This has hitherto proved impossible, however, because of the extreme difficulty encountered in hybridizing races from different subgenera or from different species of the same subgenus. There is evidence that this difficulty is the result, in some cases at least, of arrested development of the hybrid embryos. We have attempted to overcome this difficulty by excising hybrid embryos before they have become arrested and growing them in vitro. While the work is still in its infancy, some success has been obtained in that a number of interspecific hybrids otherwise unobtainable have been brought through to advanced stages of development. In one case, a hybrid has been brought through to flowering and its chromosome configuration has been obtained.

A brief description of the methods of excision and culture was given.

Planting forest trees in Indiana. DANIEL DENUYL, Purdue University.—There have been used for reforestation in Indiana 46 different species of trees; 23 hardwoods and 23 conifers, including cypress and larch. The most important factor that has influenced reforestation is the selection of species to be planted. The results of studies to determine what species of trees are best suited for reforstation show that for open field planting red pine, white pine, jack pine, virginia pine, shortleaf pine and black locust are most desirable.

Red pine *(Pinus resinosa).* This species is adapted to a wide range of planting sites and can be planted on nearly any site except badly eroded areas, extremely dry sites and poorly drained areas. It appears to be the best tree to use if a good stand of pine is desired.

White pine *(Pinus strobus).* It will grow on most sites except those that are poorly drained, extremely dry or badly gullied. It grows best in moist, protected locations.

Jack pine *(Pinus banksiana).* It will grow on nearly every site. It grows rapidly and provides a quick effective tree cover.

Virginia pine *(Pinus Virginiana)*, short leaf pine *(Pinus echinata)*. Both species are adapted for planting on worn-out, eroded lands of Southern Indiana, where they provide very quickly a dense cover for protecting the soil.

Black locust *(Robinia pseudoacacia)*. It attains its best development on well drained sites and is not adapted for planting on all eroded and depleted soils.

The planting of conifers on non-agricultural soil in Indiana appears to be the best and quickest way to eventually secure through natural succession a stand of native hardwood trees.

Plants of Cabin Creek bog, Randolph county, Indiana. RAY C. FRIESNER and JOHN E. POTZGER, Butler University.—This bog, located at the junction of Cabin Creek and state road 1, about one mile south of Farmland, is outstanding in that it is of the "raised" type. The highest elevation of the deposit, near the center of the bog, is ten feet above the margins. The elevation is associated with numerous artesian wells which flow off in three continuously flowing streams. The deepest peat and marl deposit is 33 feet. The bog is also significant from the standpoint of its vegetation, having a large number of species with disjunct distribution. Among these are: *Chara brittoni*, known elsewhere only in La Porte county Indiana and from the type locality in New Jersey; *Melica nitens, Panicum implicatum, P. albemarlense, Hierochloe odorata, Muhlenbergia setosa, Triglochin palustris, Rhyncospora capillacea, Eleocharis rostellatus, Salix lucida, Tofieldia glutinosa, Melanthium virginicum, Gerardia paupercula, Chelone glabra* var. *linifolia* forma *velutina, Lobelia kalmii,* and *Solidago ohioensis*. *Viburnum dentatum* var. *deamii* reaches its northernmost limits here.

Some trace element deficiencies in rice. NOE HIGINBOTHAM, University of Notre Dame.—Nutrient solution experiments with rice indicate that it may be added to the growing list of plants requiring boron, manganese, and copper. Boron deficiency symptoms are distinctive but resemble calcium deficiency in the appearance of chlorotic spotting of the leaves as they emerge at the tip. Manganese deficiency first appears as a chlorosis of the midvein leaf areas thus resulting in a striping of the young leaves. The minus copper plants showed no characteristic symptoms but they showed a lower dry weight than control plants. Additional experiments with boron indicate that it is essential for normal grain production and that its utilization in the plant is related to calcium supply.

The use of embryological formulas in plant taxonomy. THEODOR JUST, University of Notre Dame.—Significant stages and types of gametophyte development and embryology in flowering plants can be indicated by various symbols which in turn are grouped together as "embryological formulas." These express the available embryological data concerning any group as effectively as floral formulas convey the structure of flowers. Both types of formulas are valuable aids in the study of plant relationships.

Ecological study of the Kleine Woods, Jennings County, Indiana (Illinoian till plain). CARL O. KELLERT, Indianapolis Lutheran Schools.—The Kleine Woods is an area comprising 120 acres, located in the north central part of Jennings County. It is a remnant of the forest primeval which once covered the southeastern section of the state. Its composition is similar to that of other Illinoian till plain areas which have been studied, being a type of the mesophytic climax forest of Indiana.

In this survey, 30 different woody species were found. Of these, 14 are tall trees, 6 small trees, 3 shrubs, and 7 lianas. The dominant tall tree species in decreasing order of importance, as shown by basal area, are: *Quercus palustris*, 27.05 per cent; *Quercus alba*, 21.69 per cent; *Fagus grandifolia*, 21.61 per cent; *Liquidambar styraciflua*, 9.5 per cent; *Nyssa sylvatica*, 6.58 per cent; and *Acer rubrum*, 6.24 per cent.

Sassafras variifolium is the most important species among the small trees, and *Lindera benzoin* leads in the shrub layer.

This study is based on 50 100-square-meter quadrats. Ecological factors considered are frequency, abundance, and basal area.

A revision of the "punch-card" method for the identification of gilled mushrooms. C. L. PORTER, Purdue University.—The punch card method of mushroom identification was reported previously to the Academy. The punch cards and the arrangement of characters were demonstrated at the earlier meeting. Since that time, use of the card has suggested improvements in the method. The improvements include a change in the nature of the card; a rearrangement of characters; the elimination of some characters and the addition of others. The changes and the reasons for them are explained in this revision.

A primitive characteristic in corn from Peru. PAUL WEATHERWAX, Indiana University.—Three varieties of corn grown on the Peruvian plateau show peculiar orientations of the grains, due to the full development of the normally aborted lower flower of the spikelet.

These are described, and their theoretical significance is discussed.

Some agricultural problems of the high Andes. PAUL WEATHERWAX, Indiana University.—Many of the modern economic staples of the Andes were grown there by the Indians in pre-columbian times, and practices as to their cultivation and use have changed very little.

A brief account will be given of recent studies there with a statement as to the present status of the question of the origin of the Indian corn plant.

Some Concepts of the Respiration of Seed Plants

RAYMOND E. GIRTON,* Purdue University

In elementary botany and biology courses one occasionally hears the questions asked: "Do plants breathe?" "Is respiration the same as breathing?" "Are stomata breathing pores?" These and similar questions reveal widespread ignorance about the import and true nature of plant respiration.

Meaning of Respiration.

If we look into the meaning of the term "respiration" we find that it has its origin in the Latin prefix "re-" meaning back and the Latin verb "spiro" meaning to breathe. To respire, therefore, in the original meaning, is to breathe back, or to breathe in and out—that is, to inhale and exhale. In other words, respiration, in this usage, is synonomous with breathing.

Plants, however, do not breathe in the true sense of the term. It is conceivable that the nearest approach to actual breathing in seed plants is the result of wind which produces a swaying and bending of the stems and of the leaves also. This compression and expansion of stem and leaf tissues may produce a slight bellows action and cause a forceful exhalation and inhalation through lenticels and stomata, similar to the forced breathing in man when artificial respiration, or resuscitation, is used. Aside from this instance, the exchange of gases in plants is a diffusive process and cannot be catalogued as "breathing."

What, then is the modern usage of the term "respiration" as applied to plants? Meyer and Anderson (1939) in their text *Plant Physiology* have a clear answer to this question. They state that "plant physiologists use the term respiration primarily to refer to the oxidation of foods in living cells resulting in the release of energy." Other authors of current textbooks (Miller, 1938) and of monographs upon plant respiration are essentially in agreement with this interpretation as applied to plants. We have, therefore, emphasis placed upon a metabolic process, largely chemical in nature, whereby energy is released through the oxidation of foods within living cells. Such a definition is broad enough to include both aerobic (or oxygen) and anerobic forms of respiration.

Certain Factors and the Respiratory Gas Exchange.

Much of the early study of plant respiration was concerned with the influence of certain factors, chiefly external, upon plant respiration or upon related processes dependent on respiration. Since the exchange of gases is the outward sign of inward respiratory activity, the first step

* The writer wishes to thank the following individuals for reading the manuscript: Professors A. T. Guard, H. B. Knoll, C. L. Porter, and P. A. Tetrault

in building up a knowledge of plant respiration involved the discovery and demonstration of such an exchange. This discovery, in turn, waited upon the identification of the gases concerned in respiration. Therefore, although the Italian physician and plant anatomist Malpighi as far back as 1679 pointed out that seeds require air for their germination, progress in the subject was obliged to wait for the discovery of oxygen by Joseph Priestly in 1774. Three years later, the Swedish chemist and co-discoverer of oxygen, Scheele, was able to show that germinating seeds absorb and utilize oxygen and, at the same time, produce carbon dioxide. In 1779 the Dutch physician and plant experimenter, Ingenhousz, demonstrated that all living plants evolve carbon dioxide in darkness and that non-green plants also evolve carbon dioxide in the light as well.

A marked step in advance came with the introduction of quantitative methods of study by the Swiss plant physiologist and chemist, De Saussure, as illustrated by work published between 1797 and 1822. De Saussure measured the gas exchanges in germinating seeds and in darkened leaves, and compared the rates of oxygen consumption with those of carbon dioxide production. He found that frequently, but not always, these gases were exchanged in equal quantities. De Saussure also studied the production of water and of heat in plant respiration. Both of these he correlated with the measurable gas exchange.

Respiration is one of several physiological processes which are markedly influenced by temperature. Bonnier and Mangin in 1884 found that plant respiration, as measured by carbon-dioxide production, increases regularly with increased temperature until it finally reaches a maximum value where it remains at the same level until the death of the plant takes place at about 50°C. It was thus shown that plant respiration has no true optimum temperature.

Internal as well as external factors have also received study. Palladin, at the turn of the century, published a report of the relation of carbohydrate supply to respiratory activity. He found that when starved, etiolated leaves were floated on sugar solutions their original low rate of respiration increased many fold. Sugar supply thus may limit respiration. The work of Spoehr and McGee (1923) concerned another and perhaps unexpected internal factor which may markedly influence respiration. These writers found that in leaf tissues wherein carbohydrate supply was adequate, increased respiration rates could be obtained by adding simple amino acids.

The contributions of the foregoing men, and of many others not mentioned, illustrate the slow gathering of knowledge concerning the general nature of the respiratory gas exchange and also the influence of various factors upon this process. As a result of these findings, speculation regarding the meaning of the observed phenomena began to develop. Some of the ideas put forward have been abandoned in the light of wider knowledge. Other concepts have been modified and retained as the result of further studies and still others are now in the process of formulation, testing, and modification.

Respiratory Concepts.

One concept which seems to have been widely held over a period of forty years is that of "double respiration." Following, and in spite of, the careful work and reasoning of De Saussure, the idea became widespread that plants carry on two distinct forms of respiration which alternate during the twenty-four hour day. Thus it was thought a "diurnal" respiration took place during the daylight hours and a "nocturnal" respiration took place during the hours of darkness. The diurnal respiration was characterized by the absorption of carbon dioxide and the evolution of oxygen. The nocturnal respiration, on the other hand, resulted in the reverse gas exchange—that is, the absorption of oxygen and the evolution of carbon dioxide. This misconception can be attributed to the use of the term "respiration" for both gas exchanges. Thus, as we now know, the actual daylight respiratory gas exchange was overlooked because it was masked by the greater magnitude of the reverse gas exchange of photosynthesis.

It remained for the German plant physiologist Sachs to sound the death knell for this double-respiration concept. Sachs in 1865 emphasized what had been shown previously by others—that two separate processes contribute to the carbon-dioxide-oxygen gas exchange, namely, photosynthesis and respiration. To quote Stiles and Leach (1936) in their monograph *Respiration in Plants*, "Sachs pointed out what he later called 'the scarcely conceivable thoughlessness and obtuseness' in speaking of a double respiration of plants—of a so-called nocturnal respiration, by which was understood the evolution of carbon dioxide which occurs in true respiration."

Another nineteenth-century concept advanced in 1878 by the German botanist Pfeffer, and later abandoned by him, was the belief of a direct connection between fermentation and aerobic, or oxygen, respiration. This concept has been called the "Theory of Connection." It was borrowed from the animal physiologist Pflüger, and applied to plants by Pfeffer. Pfeffer's idea was that normal plant respiration consisted of two steps. The first step could take place under anaerobic conditions and yielded both alcohol and carbon dioxide. It was therefore considered to be identical with yeast fermentation. The second step was aerobic in character and oxidized the alcohol produced in step one completely to carbon dioxide and water. The fermentation process, therefore, was looked upon as the natural first step in the normal oxygen respiration of seed plants. (Fig. 1.)

SUGAR (hexose)
↓ (anerobic-fermentation)
ALCOHOL + CARBON DIOXIDE
↓ (aerobic)
WATER + CARBON DIOXIDE

Fig. 1 Pfeffer's Schema

In line with this concept, it was supposed that one-third of the carbon contained in the original sugar appeared as carbon dioxide in the fermentation step. This would represent the maximum yield of carbon dioxide under anaerobic conditions, as in an atmosphere of pure hydrogen, for example. The second step, which was dependent upon the presence of free oxygen, converted the carbon of the alcohol product to carbon dioxide so that all of the carbon of the original sugar would appear as carbon dioxide. Therefore, the ratio of carbon dioxide respired by plants in hydrogen to that produced in air should be one to three. This ratio could not be verified experimentally, perhaps, because of the toxic effects of the anaerobically accumulated alcohol. Also, it was shown that alcohol is less easily oxidized by plants than sugar. For these and other reasons Pfeffer virtually abandoned the view that alcoholic fermentation constitutes a part of normal seed-plant respiration. He said in 1897 as quoted in Kostyschev's (1927) *Plant Respiration*: "These primary causes, which in normal respiration bring about the oxidizing action of oxygen, in the absence of free oxygen . . . effect reactions which *did not take place* wholly or in part, reactions out of which arise carbonic acid as well as other products of intramolecular respiration."

In spite of the fact that Pfeffer himself gave up the theory of connection, the fundamental idea back of it was not dead. In 1910 and the following years, the Russian physiologist Kostyschev advocated a modification of Pfeffer's concept. (Fig. 2.) Sugar (hexose) is again

HEXOSE

↓ (zymase)

LABILE INTERMEDIATES

↓ (– oxygen) ↓ (+ oxygen)

ALCOHOL + CARBON DIOXIDE WATER + CARBON DIOXIDE

Fig. 2 Kostyschev's Schema

the starting point of his theory and under the action of zymase, demonstrable in plant tissues, produces certain labile compounds intermediate in the process of fermentation. Such compounds as acetaldehyde and pyruvic acid have been suggested as probable intermediates.

Following this first step, which is anaerobic in nature, the intermediate compounds in the presence of oxygen become oxidized to carbon dioxide and water. In the absence of free oxygen, however, some of these intermediates undergo oxidation and some undergo reduction yielding the typical fermentation products of carbon dioxide and ethyl alcohol.

Kostyschev's modification overcame at least some of the objections to the original concept. For example, the difficulty of securing a rapid oxidation of alcohol by seed plants is obviated by assigning the actual

production of alcohol to anaerobic conditions only. The main path of normal respiration thus turns aside before the final alcohol product is reached. Instead, the labile intermediate compounds are completely oxidized to the end products of oxygen respiration.

Blackman in 1928 suggested a schema which is a further modification and expansion of that of Kostyschev. (Fig. 3.) In the first place,

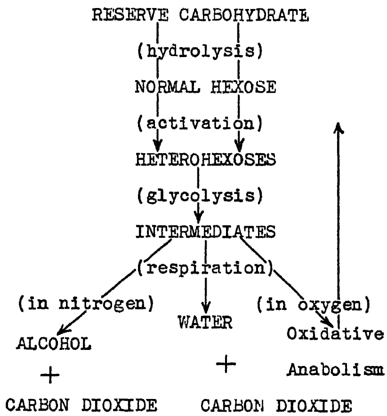

Fig. 3 Blackman's Schema

carbohydrate reserves such as starch or sucrose form the initial substrate. This necessitates a preliminary hydrolytic step to form hexose sugar. Since recent studies on the structure of sugars had described an active gamma-form of hexose, Blackman suggested that an activation step should precede the actual chemical breakdown of the hexose sugar. This cleavage step he labelled "glycolysis." It is anaerobic in nature and corresponds generally to the first step in Kostyschev's schema. Also following Kostyschev's concept, Blackman's schema gives ethyl alcohol and carbon dioxide as the final products of seed-plant respiration in nitrogen, and carbon dioxide and water as final products in oxygen (air).

There is, however, a final additional feature which Blackman has labelled "oxidative anabolism." In this step some of the carbon which might be expected to be released under aerobic conditions as carbon dioxide fails to appear. It is argued that this carbon must therefore be built back into one of the substances preceding, or intermediate in, glycolysis. This addition to the schema was included in an effort to explain the higher rates of carbon-dioxide production obtained with apple fruits in nitrogen compared to those obtained in air.

A different point of view of the respiratory process is emphasized by certain other writers. Let us look at the schema suggested by the Russian physiologist Palladin in 1908. Palladin made boiling water extractions of tissues from many different plants and found that a large proportion of the species studied contained substances which would color red or violet when treated with hydrogen peroxide and peroxidase. These extracted substances he termed "chromogens" and the oxidation products,

"respiration pigments." Palladin considered that these substances play a part in plant respiration as follows: (Fig. 4.) The chromogens could

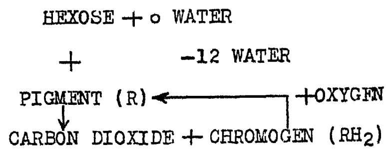

Fig. 4 Palladin's Schema

be oxidized by means of the action of oxidase and free oxygen to form respiratory pigments and water. These respiratory pigments could then bring about the oxidation of the substrates of respiration by removing hydrogen from them anaerobically. The pigments are thus reduced to form the chromogens which can be used again after oxidation in the air.

Here we have emphasis placed upon the anaerobic oxidation of the substrates of respiration. The use of free oxygen is confined to the restoration of the "hydrogen acceptor," as it is called, which in this case is the respiratory pigment. This general viewpoint is in accord with that held today concerning certain phases of cellular oxidations.

Within the past ten years several schemata which involve a series of organic acids and enzyme systems have been suggested for explaining oxidative changes taking place in living cells. One of the best known of these suggestions is that of the citric-acid cycle of Krebs as discussed by Barron (1943). This cycle, in condensed form (Fig. 5), shows

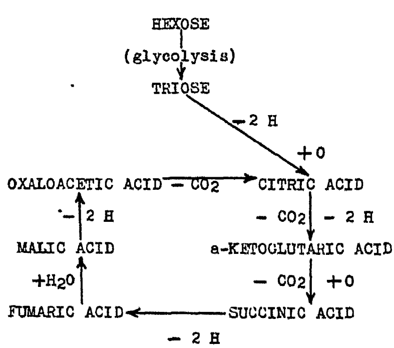

Fig. 5 Krebs Citric Acid Cycle

the oxidation of the glycolytic products of hexose sugar involving the formation of pyruvic acid which is combined with oxalacetic acid and oxidized to citric acid at the beginning of the cycle. Carbon dioxide is split off in the formation of the citric acid and in the two following steps of the condensed cycle.

The remainder of the citric-acid cycle is concerned with the regeneration of the oxalacetic acid to combine with more pyruvic acid formed by the partial oxidation of triose. Coupled with the series of acids which

make up the cycle is a system containing an oxygen activating mechanism including cytochrome and oxidase, plus appropriate dehydrogenase enzymes.

In spite of the fact that the Krebs cycle was based upon pigeon-muscle experiments, efforts have been made by Machlis (1944) and by Henderson and Stauffer (1944) to explain plant respiration upon a similar basis. Excised roots of barley and tomato were treated with oxidase and dehydrogenase inhibitors as well as with respiratory intermediates including fumarate, malate, succinate, and citrate. Studies made upon the responses in respiration to such treatments led these writers to the conclusion that some modified form of the Krebs cycle may function in the respiration of these roots.

Conclusion:

In conclusion it should be pointed out that from simple beginnings in the discovery of facts and the postulation of theories, progress in the study of plant respiration has led to an ever increasing accumulation of facts and to concepts of increasing complexity. When, and if, a complete picture of this fundamental process is eventually gained, we shall doubtless be amazed at the consummate chemist which the minute plant cell is proved to be.

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An Abnormal Fruit Character in Tomato

A. T. GUARD, Purdue University

During the summer of 1944 a single tomato plant which bore abnormal fruits occurred in a commercial field of Rutger tomatoes. The fruits of this plant varied from the normal tomato fruit in several ways; namely, there were more carpels; the carpels did not fuse and the fruits were almost completely sterile. Most of the flowers dropped shortly after blooming, but some remained on and the peculiar looking fruits grew to maturity and ripened. In the case of those fruits which ripened there was usually present a considerable amount of proliferated tissue from the center of the axis. When the older part of the fruit was red ripe this proliferated tissue at the tip of the fruit was still green.

Fig. 1. A partially matured fruit showing the unfused carpels.

This original plant was brought into the greenhouse and propogated vegetatively. One fruit from the plant produced ten seeds which, although undersize, appeared to have embryos in them. These seeds were planted and four germinated. Of the four seedlings, two grew to maturity and produced fruits like those of the parent plant.

Pollen from the original clone was used to make crosses with normal plants of the Rutger variety. This pollen seemed quite normal. F_1 plants from this cross were very vigorous and their fruits were essentially normal except that they were rougher than is characteristic of the Rutger variety.

Selfed seed from these F_1 plants was planted and from this seed 123 F_2 plants were grown to maturity. The flowers of these plants were studied and the plants classified into two groups, those having normal ovaries and those having ovaries showing the abnormal characteristics

of the pollen parent. This distinction was very sharp and no intermediate conditions were observed. Of the 123 plants studied 92 showed normal ovaries and 31 showed ovaries with the unfused carpels.

These data warrant the conclusion that this abnormal type of fruit is a heritable character which is due to a single recessive gene.

Observations of the Growth of an Injured Plant of Dirca Palustris

FRED A. LOEW, Huntington College

It is generally thought that an injury to a living organism would decrease its vitality and interfere with its continued growth and development. The following is the story of a five year observation of the relative growth of four plants of *Dirca palustris* (Leatherwood), one of which was injured.

Prior to measuring, the plants were established as follows. In the spring of 1936, three plants of *Dicra Palustris* were taken from a creek bottom of moist alluvial soil in a partly shaded locality, their natural habitat, and placed in an open location of a rather dry silt loam. In the autumn of the following year, 1937, only one of the three plants had survived, and it was somewhat deficient in vigor. In the spring of 1938, the two plants which died were replaced by three others of about the same size taken from the same habitat. During the winter of 1937-38 the surviving specimen of the first replanting was accidentally broken over a couple of inches above the ground. In the spring this plant was straightened and given support to hold the broken parts together until they were repaired. During that summer, 1938, the four plants grew but were not normal as to vigor. The growth of the following summer, 1939, was improved over that of the previous year. The injured plant showed improvement in growth and vigor and the three uninjured ones were in good condition, though not as good as those in their natural habitat. The summer of 1940 showed a noticeable improvement in growth of all four plants. The fracture of the injured plant seemed to have been repaired, only a scar in the bark remaining in sight. All four of the plants, the injured and the uninjured ones, grew well and blossomed. In the autumn of 1941 it was observed that the injured plant had made more growth than any one of the uninjured plants. No measurements were made at this time. The growth of all the plants seemed normal; they all blossomed that season.

At the close of the growing season of the next summer, 1942, measurements were started. Ten of the main branches of each of the four plants were selected as nearly uniform as possible; these were marked with wire rings. At this time measurements of the 1941 growth were made, as well as that of 1942. Total growth measurements were made each succeeding year, including 1945, a total of five years.

The measurements of the total growth in inches for each plant are tabulated below.

Uninjured plants	1941	1942	1943	1944	1945
No. 1S	24.7	24.7	25.2	21.2	15.0
No. 2E	36.0	31.0	24.7	18.5	20.0
No. 3N	27.2	17.2	31.0	22.2	26.0
Average per plant	29.3	24.3	26.9	20.6	20.3
Injured plant	52.7	34.5	27.5	23.2	18.8
Difference	23.4	10.2	00.6	2.6	—1.5

It is fully understood that there are not sufficient data from this one set of observations to make safely any satisfactory deductions as to the causes involved, yet that does not preclude suggestions as to the probable factors. Holeman and Robbins (1939, pp. 39-40), in a discussion of tropisms in relation to the curvature of plant tissue, state, "In the case of tropisms a 'one-sided' external stimulus is responsible for the occurrence as well as the direction of the curvature but the plant itself curves by reason of a different rate of growth on the two sides of the organ." After raising the question as to the cause of the different rate of growth on the two sides of the organ, they say, "It has been demonstrated that growth hormones play an important role in this phenomenon. A hormone is a substance which produced in one part of an organism is moved to another part and there is capable of influencing a specific physiological process."

From Smith, Gilbert, *et al* (1942, p. 66) this statement is quoted, "When the stem, roots or even leaves of some plants are exposed to unusual stimuli such as wounding, as for example when a branch is cut from the stem, the exposed thin-walled cells are stimulated to divide." From these two references we might be warranted in suggesting the following application to the injured *Dirca palustris* plant.

First. When this plant was broken it received an unusual stimulus which caused an unusual accumulation of growth hormones around the fractured tissue which resulted in the formation of an unusual amount of thin-walled growing tissue. The amount of growing tissue decreased each succeeding year as indicated by the table.

Second. When the fractured tissue became repaired there might have been a surplus of growth hormones which stimulated the additional growth. This surplus might have been reduced each succeeding year as the need became less after the repair was made; thus in a few years the difference between the amount of growth between the injured and the uninjured plants would be removed and a balance reached as indicated by the table.

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Indiana Plant Distribution Records, VI. 1945

This is a continuation of the annual reports intended as a supplement to Deam's "Flora of Indiana." The report comprises three sections, viz. "SPECIES," giving new county records with the location of confirming specimens; "NOMENCLATORIAL CHANGES" in which an attempt is made, within the limits and in the spirit of conservative taxonomy, to keep the "Flora" up to date in plant names; "DELETIONS" in which known previous errors of determination are corrected.

Species

Genera are listed in the order given in the "Flora" and species are given in alphabetical order under the genera. Symbols following the counties indicate the herbaria in which confirming specimens have been deposited. Species, varieties or forms new for the state are given in boldface and these, together with name changes, are followed by literature references. Cases of doubt whether a species, newly found within the state, will become a part of the state flora are preceded by an asterick.

The specimens listed below have been collected by the following collectors: Butler University (B): Charles C. Deam, Charles M. Ek, Ray C. Friesner, Ralph Kriebel, Scott McCoy, and John E. Potzger; Deam Herbarium (D) : Charles C. Deam, Ray C. Friesner, Ralph Kriebel, and John E. Potzger; Crispus Attucks High School (CA): William H. Rhoades; DePauw University (DP): Ray C. Friesner, Nancy Kreicker, Patricia O'Hair, John E. Potzger, Winona H. Welch, and T. G. Yuncker; Duke University (Du): Ray C. Friesner, R. M. Tryon, Jr.; Goshen College (Go): S. W. Witmer; Gray Herbarium (G): Ray C. Friesner; Huntington College (H): Fred Loew; Indiana University (IU): W. E. Ricker; University of Kansas (Ka): J. A. Holmes; Kriebel Private Herbarium (K): Ralph Kriebel; New York Botanical Garden (NY): Charles C. Deam, Mrs. Joseph Clemens, and Ray C. Friesner; University of Notre Dame (ND): John E. Potzger; University of Pennsylvania (Pa): Charles C. Deam; Purdue University (P): John E. Potzger; U. S. National Arborteum (USNA): Rhodora 47: 58, U. S. National Herbarium (N): John E. Potzger and Scott McCoy.

The committee maintains a card file showing published distribution of each species within the state. Botanical workers needing such information may obtain distribution maps of any species, recorded in the "Flora" or subsequently added in these reports, by requesting same from the secretary of this committee.

Botrychium dissectum, Union (D,B). *B. d.* v. *obliquum,* Lagrange (D), Scott (B). *Cystopteris fragilis* v. *protrusa,* Carroll (B), Vermillion (B). *Dryopteris hexagonoptera,* Orange (B), Union (B). *D. thelypteris* v. *pubescens,* Carroll (B), Huntington (D). *Polystichum*

acrostichoides, Union (B). *P. a.* f. *incisum,* Harrison (D). *Athyrium angustum* v. *rubellum,* Scott (B). *A. pycnorcarpon,* Vermillion (B). *Asplenium cryptolepis,* Harrison (B). *A. platyneuron,* Scott (B). *Equisetum arvense,* Randolph (B). *E. nelsoni,* Clinton (B), La Porte (B). *E. prealtum,* Union (B).

Juniperus virginiana v. *crebra,* Scott (B), Union (B). *Typha latifolia,* Harrison (D). *Najas flexilis,* Harrison (D, B). *Alisma subcordatum,* Orange (D). *Bromus commutatus,* Elkhart (B), Putnam (B), Vermillion (B). *B. inermis,* Elkhart (B). *B. japonicus,* Harrison (D, B), Vermillion (B). *B. purgans,* Vermillion (B). *B. secalinus,* Randolph (B). *B. tectorum,* Randolph (B), Vermillion (B). *Festuca elatior,* Randolph (B). *F. obtusa,* Vermillion (B). *F. ovina,* Elkhart (B), Lagrange (B). *F. rubra,* Lagrange (B).

Glyceria septentrionalis, Vermillion (B). *G. striata,* Randolph (B), Vermillion (B). *Poa annua,* Randolph (B), Starke (B), Steuben (B), Vermillion (B). *P. compressa,* Huntington (H), Vermillion (B). *P. paludigena,* Elkhart (D, B). *P. palustris,* Elkhart (B). *P. pratensis,* Blackford (B), De Kalb (B), Huntington (H), Randolph (B). *Eragrostis cilianensis,* Orange (D), Union (B), Vermillion (B). *E. frankii,* Clinton (B), Harrison (D), Union (B), Wayne (B). *E. pectinacea,* Union (B). *E. spectabilis,* Union (B).

Dactylis glomerata, Elkhart (B), Huntington (H), Randolph (B). *Melica nitens,* Randolph (B). *Triodia flava,* Delaware (B), Jasper (B), Starke (B), Union (B). *Agropyron repens,* Huntington (H), Orange (D). *Elymus villosus,* Carroll (B). *E. virginicus* v. *australis,* Harrison (D). *E. v.* v. *intermedius,* Harrison (D). *Hystrix patula,* Vermillion (B). *Hordeum jubatum,* Randolph (B). *H. pusillum,* Vermillion (B). *Koeleria cristata,* Elkhart (D, B). *Danthonia spicata,* Vermillion (B). *Calamagrostis canadensis,* Vermillion (B). *Agrostis alba,* Blackford (B), Vermillion (B). *A. hyemalis,* Vermillion (B). *A. perennans,* Orange (B), Union (B), Vermillion (B). *Cinna arundinacea,* Orange (B).

Phleum pratense, Elkhart (B), Lagrange (B), Vermillion (B). *Muhlenbergia frondosa,* Clinton (B), Delaware (B), Wayne (B). *M. mexicana,* Carroll (B), Delaware (B), La Porte (B), Starke (B). *M. schreberi,* Orange (B), Randolph (B). *M. sobolifera,* Huntington (D). *M. sylvatica,* Vermillion (B), Crawford (D), Harrison (D). *M. tenuiflora,* Rush (B). *Sporobolus asper,* Jasper (B). *S. clandestinus,* Jasper (B). *S. heterolepis,* Cass (B). *S. neglectus,* Carroll (B), Jasper (B), Union (B). *S. vaginiflorus,* Madison (B), Randolph (B), Union (B). *Stipa avenacea,* Elkhart (B). *A. longispica,* Orange (B). *A. oligantha,* Crawford (D).

Eleusine indica, Clinton (B). *Hierochloë odorata,* Randolph (B). *Bouteloua curtipendula,* Harrison (D, B, K), Vermillion (B). *Leersia oryzoides,* La Porte (B), Orange (B). *L. virginica,* Blackford (B), Orange (D, B). *Digitaria ischaemum,* Orange (B), Union (B). *D. sanguinalis,* Clinton (B), Delaware (B), Orange (B), Vermillion (B). *Leptoloma cognatum,* Clinton (B), Noble (B), Union (B), Vermillion (B).

Paspalum circulare, Jasper (B), Orange (D). *P. pubiflorum* v. *glabrum*, Orange (B).

Panicum addisoni, Elkhart (B). *P. agrostoides*, Crawford (D), Switzerland (K, B). *P. boscii*, Vermillion (B). *P. capillare*, Crawford (D). *P. clandestinum*, Vermillion (B). *P. depauperatum*, Elkhart (B), Noble (B). *P. dichotomiflorum*, Harrison (D), Huntington (D). *P. dichotomum*, Vermillion (B). *P. flexile*, Jasper (B).*P. gattingeri*, Union (B). *P. huachucae*, Vermillion (B). *P. implicatum*, Randolph (B). *P. latifolium*, Vermillion (B). *P. linearifolium* v. *werneri*, Harrison (D, B). P. **longifolium** Torr., Hitchcock, Man. Grasses U. S., p. 679. Collected by J. E. Potzger. Starke (B, D, DP, H, IU, N, ND, P). *P. microcarpon*, Orange (B). *P. oligosanthes*, Elkhart (B, D). *P. philadelphicum*, Orange (B). *P. pseudopubescens*, Elkhart (D, B). *P. stipitatum*, Orange (D, B). *P. tsugetorum*, Elkhart (B).

Echinochola crusgalli, Huntington (H), Orange (D). *Setaria italica*, Jasper (B). *S. lutescens*, Delaware (B), La Porte (B), Orange (D, B), Vermillion (B). *E. viridis*, Huntington (H), La Porte (B). *Andropogon elliottii*, Crawford (D). *A. scoparius*, Randolph (B). *A. virginicus*, Carroll (B), Union (B). *Sorghastrum nutans*, Carroll (B), Delaware (B).

Eleocharis acicularis v. *typica*, Harrison (D). *E. quadrangulata* v. *crassior*, Switzerland (K, D, B). *Carex frankii*, Huntington (H), Orange (D). *C. grayii* v. *hispidula*, Harrison (D). *C. picta*, Jennings (K, D, B). *C. rosea*, Huntington (H). *C. scoparia*, Tippecanoe (B). *C. typhina*, Orange (D). *C. umbellata*, Lagrange (B, D, G, NY, Mi). *Symplocarpus foetidus*, Randolph (B). *Commelina communis*, Vermillion (B). *Tradescantia ohioensis*, Vermillion (B). *Juncus diffusissimus*, Orange (D). *J. marginatus*, Harrison (D), Washington (D). *J. tenuis* f. *anthelatus*, Orange (D). *Luzula multiflorus* v. *bulbosa*, Orange (D).

Melanthium virginicum, Randolph (B). *Allium canadense*, Vermillion (B). *Smilacina racemosa* v. **cylindrata** Fern. Rhodora 40: 406. 1938; Amer. Midland Nat. 33: 644-666. 1945. Bartholomew (D, B), Boone (D), Brown (D), Carroll (D), Clark (D), Crawford (D), Daviess (D), Dearborn (D, B), Decatur (D, B), De Kalb (B), Delaware (D), Dubois (D), Elkhart (D), Fayette (D, B), Fountain (D, B), Franklin (D, B), Fulton (B), Gibson (D), Grant (B), Hancock (D), Hendricks (B), Howard (D, B), Jackson (D, B), Jasper (B), Johnson (D, B), Knox (B), Lagrange (D, B), Lake (D), La Porte (B), Marion (D, B), Marshall (D), Noble (D, B), Ohio (B), Owen (B), Parke (B), Perry (D), Pike (D), Porter (D, B), Posey (D, B), Pulaski (B), Ripley (D), Rush (B), Scott (D), Shelby (B), Spencer (D, B), St. Joseph (B), Sullivan (D), Tippecanoe (B), Vermillion (B), Wabash (B), Warren (D, B), Warrick (D), Washington (D), Wells (B), Whitely (D).

S. r. v. *typica* Fern., Adams (D), Allen (D), Blackford (D), Boone (D), Cass (D), Clinton (D, B), Crawford (B), Elkhart (B), Fulton (D), Grant (D), Greene (D), Huntington (D), Hamilton (D), Harrison (D), Jasper (D), Jay (D), Jefferson (D, B), Jennings (D), Kosciusko

(D), La Porte (D), Lawrence (D), Madison (B), Marion (D, B), Marshall (D), Martin (D), Miami (D, B), Montgomery (D, B), Morgan (D), Newton (D), Ohio (D), Orange (D), Parke (D), Posey (D), Pulaski (D), Putnam (D), Randolph (D, B), Ripley (B), Rush (D, B), Starke (D), Steuben (D), St. Joseph (D), Switzerland (D), Wabash (D), Wells (D), White (D).

Maianthemum canadense v. *interius,* Elkhart (D, B). *Trillium flexipes* f. *walpolei,* Morgan (B), Randolph (B). *T. recurvatum* f. *luteum,* Putnam (DP). *T. sessile* f. *luteum,* Putnam (DP). *Smilax ecirrhata,* Randolph (B). *S. glauca,* Scott (B). *S. hispida,* Scott (B), Union (B), Vermillion (B). *Hypoxis hirsuta,* Randolph (B). *Dioscorea quaternata,* Scott (B). *Iris virginica* v. *shrevei,* Randolph (B). *Cypripedium calcelous* v. *pubescens,* Vermillion (B). *C. reginae,* Elkhart (D, B), Randolph (B). *Orchis spectabilis,* Miami (B).

Populus deltoides, Harrison (D). *Juglans cinerea,* Huntington (H). *J. nigra,* Union (B), Vermillion (B). *Carya cordiformis,* Orange (B), Union (B). *C. laciniosa,* Blackford (B), Carroll (B), Huntington (H), Union (B). *C. ovalis* v. *obcordata,* Wells (D, B). *C. o.* v. *obovalis,* Wells (D, B). *C. tomentosa,* Elkhart (D), Vermillion (B). *Carpinus caroliniana* v. *virginiana,* Carroll (B), Vermillion (B). *Ostrya virginiana,* Vermillion (B). *O. v.* f. *glandulosa* Scott (B), Union (B). *Corylus americana,* Scott (B). *Betula pumila* v. *glandifera,* Elkhart (B). *Alnus rugosa,* Washington (D). *Fagus grandifolia,* Scott (B), Union (B), Vermillion (B). *Quercus alba,* Scott (B). *Q. bicolor,* Carroll (B). *Q. borealis* v. *maxima,* Union (B), Vermillion (B). *Q. macrocarpa,* Carroll (B), Union (B). *Q. muhlenbergii,* Union (B). *Q. palustris,* Orange (B). *Q. velutina,* Scott (B), Vermillion (B).

Ulmus americana f. **alba** (Ait.) Fern. Rhodora 47: 133. 1945. Blackford (B), Carroll (B), Jefferson (B), Orange (B), Scott (B), Union (B), Vermillion (B). *U. rubra* Muhl. Rhodora 47: 203-204. 1945. Carroll (B), Union (B). *U. thomasi,* Carroll (B). *Celtis occidentalis* v. *crassifolia,* Blackford (B), Union (B), Vermillion (B). *Morus alba* v. *tatarica,* Union (B). *M. rubra,* Carroll (B), Orange (B), Scott (B), Union (B), Vermillion (B). *Maclura pomifera,* Union (B). *Humulus americanus,* Clinton (B). *Urtica procera,* Scott (B), Vermillion (B), Washington (B). *Laportea canadensis,* Clinton (B), Crawford (D), Huntington (H), Jasper (B), Starke (B). *Pilea pumila,* Washington (B). *Boehmeria cylindrica,* Orange (B), Vermillion (B). *Parietaria pennsylvanica,* Union (B).

Polygonum neglectum, Vermillion (B). *P. pennsylvanicum* v. *laevigatum,* Orange (B), Vermillion (B). *P. persicaria,* Huntington (H), Union (B). *P. punctatum,* Orange (B), Scott (B), Union (B). *P. scandens,* Blackford (B). *P. virginianum,* Huntington (H). *Chenopodium ambrosioides* ssp. *eu-ambrosioides,* Scott (B). *C. botrys,* Union (B). *Atriplex patula* v. *littoralis,* Lagrange (D). *Salsola pestifer,* Union (B). *Amaranthus albus* L. Rhodora 47: 139-140. 1945. Harrison (D). *Acnida tamariscina,* Union (B). *Phytolacca americana,* Union (B). *Mollugo*

verticillata, Bartholomew (B), Union (B), Vermillion (B). *Cerastium vulgatum* v. *hirsutum* f. *glandulosum,* Blackford (B). *Silene cserei,* Brown (B). *Lychnis alba,* Tippecanoe (B). *Saponaria officinalis,* Clinton (B).

Nuphar advena, Washington (D). *Aquilegia canadensis,* Randolph (B). *Anemone canadensis,* Delaware (B). *Hepatica americana,* Noble (B). *Clematis virginiana,* Harrison (D), Orange (D, B). *Ranunculus abortivus,* Huntington (H). *R. flabellaris,* Henry (B). *R. sceleratus,* Jasper (B). *Thalictrum dasycarpum,* Harrison (D). *Menispermum canadense,* Blackford (B), Scott (B), Vermillion (B). **Magnolia tripetala** L. Gray Man. 7ed p. 409. Collected by Charles C. Deam. Crawford (D, B, C, G, K, NY, O, SW). *Liriodendron tulipifera,* Scott (B), Union (B). *Asimina triloba,* Blackford (B), Carroll (B), Orange (B), Union (B). *Sassafras albidum,* Carroll (B), Noble (B), Scott (B), Vermillion (B). *S. a.* v. *molle,* Union (B). *Lindera benzoin,* Scott (B).

Lepidium campestre, Owen (B). *L. virginicum* v. *typicum,* Blackford (B), Vermillion (B). *Thlaspi arvense,* Randolph (B). *Sisymbrium altissimum,* Brown (B), Vermillion (B). *S. officinale* v. *leiocarpum,* Vermillion (B). *Rorippa islandica* v. *microcarpa,* Delaware (B). *R. sylvestris,* Vermillion (B). *Armoracia rusticana,* Huntington (H). *Cardamine douglassii,* Randolph (B). *Capsella bursa-pastoris,* Huntington (H). *Descurainea pinnata* v. *brachycarpa,* Cass (B). *Penthorum sedioides,* Union (B). *Heuchera americana* v. *brevipetala,* Randolph (B). *H. richardsonii* v. *grayana,* Noble (B). *Hydrangea arborescens,* Vermillion (B). *Grossularia hirtella,* Elkhart (B). *Hamamelis virginiana,* Blackford (B). *Platanus occidentalis,* Carroll (B), Clinton (B).

Crataegus mollis, Huntington (H). **Rubus nescius** Bailey. Gentes Herbarum 5: 808. 1945. Harrison (D). Collected by Charles C. Deam. *R. occidentalis,* Blackford (B), Union (B). *Fragaria virginiana,* Huntington (H). *F. v.* v. *illinoensis,* Jefferson (B). *Potentilla recta,* Blackford (B), Carroll (B), Huntington (H). *Geum canadense,* Vermillion (B). *G. virginianum,* Vermillion (B). *Filipendula rubra,* Delaware (B). *Agrimonia parviflora,* Huntington (H), Orange (B). *Rosa palustris,* Randolph (B). *Prunus lanata,* Harrison (B). *P. serotina,* Scott (B), Union (B).

Cercis canadensis, Randolph (B). *Cassia hebecarpa,* Crawford (B). *Gleditsia triacanthos,* Carroll (B), Union (B). *G. t.* f. *inermis,* Wells (D). *Medicago lupulina,* Blackford (B), Vermillion (B). *Melilotus alba,* Blackford (B), Vermillion (B). *M. officinalis,* Vermillion (B). *Trifolium hybridum* v. *elegans,* Blackford (B), Vermillion (B). *T. pratense,* Vermillion (B). *T. procumbens,* Blackford (B). *Petalostemum candidum,* Vermillion (B). *Robinia pseudo-acacia,* Union (B). *Stylosanthes biflora,* Crawford (D). *Desmodium bracteosum,* Crawford (D), Huntington (D, H), Union (B). *D. ciliare,* Harrison (D). *D. glutinosum,* Union (B). *D. illinoense,* Vermillion (B). *D. paniculatum,* Huntington (H). *D. p.* v. *pubens,* Crawford (D), Harrison (D). *D. pauciflorum,* Crawford (D),

Orange (D). *D. rotundifolium,* Huntington (D). *D. sessilifolium,* Harrison (D). *D. viridiflorum,* Crawford (D). *Lespedeza violacea,* Crawford (D), Huntington (D, H). *Lathyrus palustris* v. *linearifolius,* Elkhart (B), Randolph (B). *L. venosus* v. *intonsus,* Noble (B). *Clitoria mariana,* Harrison (D, B). *Amphicarpa bracteata* v. *comosa,* Union (B). *Apios americana,* Harrison (B). *Phaseolus polystachios* v. *typica,* Crawford (D, B). *Strophostyles helveola,* Huntington (H), Washington (D).

Geranium carolinianum v. *confertiflorum,* Vermillion (B). *G. maculatum,* Henry (B). *G. pusillum,* Lagrange (D, B). *Oxalis europaea,* Huntington (H). *O. e.* f. *cymosa,* Blackford (B), Orange (B). *O. e.* f. *villicaulis,* Jasper (B). *O. stricta,* Union (B). *O. s.* v. *piletocarpa,* Vermillion (B). *Linum medium* v. *texanum,* Crawford (D, B), Harrison (D, B). *L. striatum,* Elkhart (B). *Zanthoxylum americanum,* Union (B). *Acalypha rhomboidea,* Orange (B), Scott (B). *Euphorbia commutata,* Randolph (B). *E. cyparissias,* Harrison (D). *E. dentata,* Starke (B), Union (B). *E. heterophylla,* Carroll (B). *E. maculata,* Orange (B), Union (B). *E. supina,* Union (B). *Rhus copallina* v. *latifolia,* Orange (D). *R. glabra,* Union (B). *R. radicans,* Union (B). *R. r.* v. *littoralis,* Crawford (D). *R. vernix,* Carroll (B), Huntington (D, H). *Euonymus americanus,* Orange (B). *Celastrus scandens,* Union (B).

Acer nigrum, Carroll (B), Union (B). *A. rubrum,* Blackford (B), Orange (B). *A. saccharum,* Scott (B), Union (B). *A. s.* v. *rugelii,* Lagrange (B). *Impatiens biflora,* Orange (B). *Rhamnus lanceolata,* Randolph (B). *Vitis vulpina,* Vermillion (B). *Parthenocissus quinquefolia,* Blackford (B). *P. q.* v. *hirsuta,* Union (B). *Tilia heterophylla,* Franklin (B). *Abutilon theophrasti,* Huntington (H). **Sphaeralcea remota** (Greene) Fern. Gray Man. 7ed. p. 566. Collected by S. W. Witmer. Elkhart (B, D, G, Go, NY, SW). *Sida spinosa,* Huntington (H), Washington (D). *Hypericum mutlium,* Orange (D, B), Randolph (B), Vermillion (B). *Lechea minor,* Newton (D, B). *Viola cucullata,* Elkhart (D, B).

Rotala ramosior v. *typica,* Harrison (D). *Ammania coccinea,* Harrison (D). *Rhexia virginica,* Harrison (D). *Ludwigia alternifolia,* Orange (B). *L. palustris* v. *americana,* Orange (D). *L. polycarpa,* Orange (D). *Epilobium coloratum,* Huntington (D, H). *Oenothera pycnocarpa,* Crawford (D), Huntington (H), Union (B). *Circaea quadrisulcata* v. *canadensis,* Vermillion (B). *Aralia spinosa,* Bartholomew (B). *Panax quinquefolius,* Noble (B). *Sanicula canadensis* v. *grandis,* Blackford (B), Scott (B). *S. c.* v. *typica,* Blackford (B), Scott (B), Vermillion (B), Washington (B). *Chaerophyllum procumbens,* Owen (B). *Osmorhiza longistylis,* Randolph (B). *Cicuta maculata,* Crawford (D), Delaware (B). *Sium sauve,* Carroll (B). *Thaspium barbinode,* Randolph (B). *T. trifoliatum v. flavum,* Blackford (B), Carroll (B). *Angelica purpurea,* Delaware (B). *Oxypolis rigidior,* Carroll (B). *Pastinaca sativa,* Vermillion (B). *Daucus carota,* Orange (D), Vermillion (B).

Nyssa sylvatica v. *caroliniana*, Bartholomew (B), Union (B). *N. s.* v. *typica*, Newton (D), Orange (B), Scott (B), Switzerland (K, B). *Cornus drummondii*, Clinton (B), Harrison (B). *C. femina*, Orange (B), Washington (D, B). *C. florida*, Union (B). *C. stolonifera*, Huntington (D), *Samolus parviflorus*, Orange (B). *Lysimachia ciliata*, Harrison (D), Randolph (B), Union (B). *L. nummularia*, Elkhart (B). *Dodecatheon meadia*, Randolph (B). *Fraxinus americana*, Blackford (B), Orange (B), Scott (B), Union (B). *F. lanceolata*, Carroll (B). *F. nigra*, Carroll (B). *F. quadrangulata*, Carroll (B), Union (B). *Gentiana flavida*, Harrison (D, K, B). *G. procera*, Huntington (D). ***Nymphoides peltatum** (S. P. Gmel.) Britten & Rendle, Gray Man. 7ed. p. 661. Collected by W. E. Ricker. Marshall (IU).

Acerates viridiflora, Noble (B). *Asclepias incarnata*, Vermillion (B). *A. syriaca*, Washington (B). *A. tuberosa* ssp. **interior** Woodson. Missouri Bot. Gard. Ann. 31: 368-369. 1944. Harrison (D, B), Kosciusko (B), Vermillion (B). *Ampelamus albidus*, Orange (B). *Gonobolis gonocarpos*, Harrison (B). *Cuscuta cephalanthi*, Huntington (D). *Ipomoea hederacea*, Union (B). *I. pandurata* v. *rubescens*, Harrison (D), Vermillion (B). *Phlox amplifolia*, Vermillion (B). *P. maculata*, Crawford (B). *P. paniculata*, Clinton (B), Huntington (H). *Hydrophyllum canedense*, Vermillion (B). *Hackelia virginiana*, Huntington (H). *Verbena bracteata*, La Porte (B), Madison (B), Warren (Ka.). X *V. perriana* Moldenke, Johnson (CA). *V. simplex*, Jay (B). *V. urticaefolia*, Vermillion (B).

Teucrium canadense, Elkhart (B). *T. c.* v. *virginicum*, Blackford (B), Vermillion (B). *T. occidentale* v. *boreale*, Vermillion (B). *Scutellaria nervosa* v. **calvifolia** Fern., Rhodora 47: 174. 1945. Adams (D), Allen (D), Bartholomew (D), Clark (D), Daviess (D), DeKalb (B), Gibson (D), Greene (D), Harrison (D), Jackson (D, B, G), Jennings (D), Knox (D), Lawrence (D), Monroe (D,) Posey (D, B), Vanderburgh (D), Warrick (D), Washington (D), Wells (D). *S. n.* v. *typica*, Crawford (D), Dearborn (D), Dubois (D), Orange (D), Perry (D), Pike (D), Spencer (D, B), Switzerland (D), Warren (D). *S. ovata* v. *versicolor*, Vermillion (B). *Agastache scrophularifolia*, Crawford (D), Vermillion (B). *Nepeta cataria*, Huntington (H), Vermillion (B). ***Dracocephalum parviflorum** Nutt., Gray Man. 7ed., p. 697. Collected by Winona H. Welch. Putnam (DP). *Prunella vulgaris* v. *lanceolata*, Huntington (H). *Physostegia speciosa*, Harrison (D).

Stachys tenuifolia v. *hispida*, Union (B). *S. t.* v. *typica*, Orange (D), Vermillion (B). *Monarda clinopodia*, Union (B). *Blephilia hirsuta*, Crawford (D), Scott (B). *Hedeoma hispida*, Tippecanoe (B). *Pycnanthemum flexusoum*, Scott (B). *P. incanum*, Harrison (D). *P. pilosum*, Vermillion (B). *P. virginianum*, Huntington (H). *Lycopus americanus*, Huntington (H). *Mentha arvensis*, Huntington (H). *M. piperita*, Crawford (D). *M. spicata*, Union (B). *Collinsonia canadensis*, Union (B), Washington (D). *Lycium halimifolium*, Carroll (B). *Physalis ambigua*, Delaware (B). *P. heterophylla*, Huntington (H). *P. pubescens*, Harrison (D, B). *P. subglabrata*, Huntington (H), Union (B). *Solanum caro-*

linense, Blackford (B), Carroll (B), Huntington (H), Orange (B), *S. dulcamara,* Huntington (H). *S. nigrum,* Huntington (H). *Datura stramonium,* Harrison (D), Union (B).

Verbascum thapsus, Blackford (B). *Linaria canadensis,* Lagrange (B). *Chaenorrhinum minus,* Blackford (B), Tippecanoe (B). *Scrophularia marilandica,* Vermillion (B). *Chelone glabra* v. *linifolia,* Huntington (H). *C. g.* v. *tomentosa,* Huntington (D). **Penstemon grandiflorus** Nutt., Rydb. Fl. Prairies & Plains, p. 713. Collected by Charles C. Deam, Ray C. Friesner, John E. Potzger and John Seybert. Elkhart (D, B, G). *Mimulus alatus,* Orange (D, B). *M. ringens,* Tippecanoe (B), Vermillion (B). *Leucospora multifida,* Orange (D). *Lindernia anagallidea,* Orange (D). *L. dubia* v. *riparia,* Orange (D), Washington (D). *Veronica peregrina* v. *typica,* Huntington (H). *Veronicastrum virginicum,* Vermillion (B). *Besseya bullii,* Lagrange (B). *Gerardia tenuifolia* v. *parviflora,* Vermillion (B). *Pedicularis lanceolata,* Huntington (D). *Campsis radicans,* Huntington (H). *Orobanche ludoviciana* v. *genuina,* Harrison (D).

Ruellia caroliniensis v. **cheloniformis** Fern., Rhodora 47: 80-81. 1945., Crawford (D, B, NY), Jefferson (NY), Warrick (D). *R. c.* v. **dentata** (Nees) Fern., Rhodora 47: 83. 1945., Floyd (D). *R. c.* v. **membranacea** Fern., Rhodora 47: 75-78. 1945., Clark (D), Spencer (D), Washington (D). *R. c.* v. **nanella** Fern., Rhodora 47: 79-80. 1945., Clark (D), Floyd (D, B). *R. c.* v. **salicina** Fern., Rhodora 47: 81-82. Clark (H). *R. c.* v. **semicalva** Fern., Rhodora 47: 73-75. 1945., Crawford (D), Dubois (D), Floyd (D, B), Perry (D). *R. c.* v. *typica* .Fern., Rhodora 47: 71-73. 1945., Crawford (B), Orange (D), Washington (D). *R.* **humilis** v. **calvescens** Fern., Rhodora 47: 60. 1945., Crawford (D, Pa). *R.* **h.** v. **expansa** Fern., Rhodora 47: 58. 1945, Gibson (D), La Porte (D), Montgomery (N), Tippecanoe (B, USNA), Warren (D), Vermillion (B). *R.* **h.** v. **frondosa** Fern., Rhodora 47: 54. 1945, Benton (D, B), Cass (D, B), Clinton (B), Daviess (D), Elkhart (D), Floyd (B), Gibson (D), Greene (D), Hancock (B), Harrison (D, B, Du, NY), Jasper (D), Knox (B). Lagrange (D), Lawrence (D), Madison (D), Marion (D, B, G), Miami (D, B), Newton (D, B), Posey (D), Pulaski (D), Tippecanoe (D, B), Vermillion (D), Warren (D, NY), Wells (D), White (D, B). *R.* **h.** v. **typica** Fern., Rhodora 47: 51. 1945, Clinton (B), Crawford (D), Floyd (D, NY), Hancock (B), Harrison (D, B), Knox (D), Orange (B), Posey (D), Spencer (D), St. Joseph (NY), Sullivan (D), Warren (D, Du). *R.* **h.** v. **typica** f. **grisea,** Harrison (B). *R. strepens,* Blackford (B), Cass (B), Ohio (B), Switzerland (B). *R. s.* f. *cleistantha,* Henry (B), Howard (D, B), Jennings (D), Knox (B), Montgomery (B).

Dianthera americana, Crawford (D). *Plantago aristata,* Huntington (H), Orange (B), Vermillion (B). *P. lanceolata,* Vermillion (B). *P. purshii,* Elkhart (D, B). *P. virginica,* Lagrange (B). *Houstonia longifolia,* Vermillion (B). *Cephalanthus occidentalis,* Orange (B), Vermillion (B). *Galium asprellum,* Delaware (B), Huntington (H), Randolph (B). *G. boreale* v. *intermedium,* Noble (B). *G. circaezans* v. *hypomalacum,* Orange (D). *G. c.* v. *typicum,* Scott (B). *G. concinnum,* Scott

(B), Union (B). *Sambucus canadensis,* Union (B). *Viburnum acerifolium,* Scott (B). *V. lentago,* Randolph (B). *Triosteum perfoliatum,* Cass (B), Huntington (D). *Lonicera japonica,* Washington (D). *L. xylosteum,* Elkhart (D, B). *Specularia perfoliata,* Vermillion (B). *Lobelia cardinalis,* Harrison (D, B). *L. inflata,* Orange (D, B), Scott (B), Union (B), Vermillion (B). *L. puberula,* Switzerland (K, B). *L. siphilitica,* Orange (B), Union (B).

Vernonia altissima, Orange (B). *V. missurica,* Crawford (D, B). *Eupatorium altissimum,* Huntington (D), Jasper (B). *E. perfoliatum,* Henry (B), Orange (D, B). *E. purpureum,* Orange (B). *E. rugosum,* Orange (B). *E. serotinum,* Orange (B), Scott (B), Union (B). *Solidago altissima,* Clinton (B), Vermillion (B). *S. caesia,* Union (B). *S. canadensis* v. *gilvocanescens,* Henry (B). *S. gigantea,* Harrison (B), Jasper (B). *S. g.* v. *leiophylla,* Crawford (D), Harrison (D, B), Union (B). *S. graminifolia* v. *media,* Noble (B). *S. g.* v. *nuttallii,* Carroll (B), Union (B). *S. juncea,* Orange (D). *S. latifolia,* Union (B). *S. missouriensis* v. *fasciculata* Holz, Vermillion (B). *S. nemoralis,* Noble (B), Union (B). *S. ohioensis,* Carroll (B), Randolph (D, B). *S. rigida,* Vermillion (B). *S. rugosa,* Switzerland (K, D, B). *S. uniligulata,* Huntington (D).

Aster ericodies, Lagrange (D), Newton (D). *A. e.* v. *prostratus,* Lagrange (D). *A. lucidulus,* Huntington (D). *A. oblongifolius* v. *angustatus,* Harrison (D, B.) *A. pilosus,* Orange (B), Scott (B), Union (B). *A. praealtus,* Huntington (D, B). *A. p.* v. *angustior,* Newton (D). *Erigeron annuus,* Blackford (B), Vermillion (B). *E. canadensis,* Orange (B), Vermillion (B). *Silphium integrifolium,* Randolph (B). *S. i.* v. *deamii,* Tippeacanoe (B). *S. laciniatum,* Vermillion (B). *Ambrosia elatior,* Henry (B), Union (B). *A. trifida,* Henry (B). *Xanthium pennsylvanicum,* Union (B). *Eclipta prostratus* (L.) L., Rhodora 47: 196., Orange (D). *Rudbeckia deamii,* Crawford (D, B, K), Harrison (D, B, K), Huntington (D), Orange (D), Union (D, B). *R. fulgida,* Crawford (D, B). *R. hirta,* Carroll (B), Orange (D), Vermillion (B). *R. laciniata,* Washington (D). *R. triloba,* Switzerland (K, D, B). *Actinomeris alternifolia,* Union (B). *Coreopsis tripteris,* Huntington (H).

Bidens aristosa v. *mutica,* Jasper (B), Scott (D, B). *B. bipinnata,* Orange (B). *B. comosa,* Huntington (D, H), Union (B). *B. vulgata,* Huntington (D). *Anthemis cotula,* Blackford (B), Huntington (H), Vermillion (B). *Achillea millefolium,* Vermillion (B). *Chrysanthemum leucanthemum* v. *pinnatfidum,* Vermillion (B). *Artemisia annua,* Harrison (D), Union (B). *Erechtites hieracifolia,* Crawford (B), Orange (B). *Cacalia atriplicifolia,* Union (B). *Cirsium arvense,* Blackford (B). *C. discolor,* Henry (B), Union (B). *C. muticum,* Carroll (B). *Cichorium intybus,* Huntington (H), Union (B), *Tragopogon pratensis,* Brown (B), Madison (B), Starke (B). *Lactuca biennis,* Crawford (D), Huntington (H), Scott (B). *L. canadensis* v. *longifolia* (Michx.) Farwell, Rhodora 40: 480, Vermillion (B). *L. scariola,* Clinton (B), Union (B). *L. s.* v. *integrata,* Jasper (B). *L. villosa,* Harrison (D, B). *Prenanthes altissima,* Noble (B). *P. aspera,* Harrison (B). *P. gronovii,* Orange (D).

Deletions

The following deletion should be made from the State Flora Catalog: *Helianthus annuus*, drop Lake county.

Additional Species Added to the Deam Herbarium

The following species previously reported in other herbaria for certain counties have been added to the Deam herbarium since the last report.

Botrychium dissectum v. *obliquum*, Marion. *Sagittaria brevirostra*, Harrison. *Elymus canadensis*, Huntington. *E. virginicus*, Huntington. *Cinna arundinacea*, Huntington. *Panicum anceps*, Harrison. *Sorghastrum nutans*, Huntington. *Salix discolor*, Huntington. *Carya cordiformis*, Huntington. *Quercus borealis* v. *maxima*, Huntington. *Q. imbricaria*, Harrison. *Cannabis sativa*, Lagrange. *Mollugo verticillata*, Washington. *Rorippa sessiliflora*, Harrison. *Penthorum sedioides*, Harrison. *Parnassia glauca*, Huntington. *Liquidambar styraciflua*, Harrison. *Filipendula rubra*, Huntington. *Tephrosia virginiana* v. *holosericea*, Harrison. *Amphicarpa bracteata*, Huntington. *Oxypolis rigidior*, Huntington.

Stachys tenuifolia, Harrison. *Lindernia dubia* v. *riparia*, Harrison. *Dasistoma macrophylla*, Harrison. *Epifagus virginiana*, Marion. *Lobelia siphilitica*, Washington. *Eupatorium perfoliatum*, Huntington. *E. rugosum*, Huntington. *Solidago caesia*, Huntington, Marion. *S. graminifolia* v. *nuttallii*, Huntington, *S. riddellii*, Huntington. *Aster novae-angliae*, Huntington. *A. pilosus*, Lagrange. *Helianthus tuberosus*, Huntington. *Bidens frondosa*, Huntington. *Helenium autumnale*, Huntington. *Cirsium muticum*, Huntington.

Nomenclatorial Changes

The following changes in names of Indiana plants are considered by the committee to be likely of acceptance by taxonomists generally. Other name changes have recently appeared in the literature but are temporarily withheld from this list awaiting further evidence of their merit and likelihood of general acceptance.

Pteretis nodulosa (Michx.) Nieuwland to
P. pennsylvanica (Willd.) Fern.
Rhodora 47: 123. 1945

P. nodulosa f. pubescens (Terry) Fern. to
P. pennsylvanica f. **pubescens** (Terry) Fern.
Rhodora 47: 124. 1945

Dryopteris thelypteris v. pubescens (Lawson) Prince to
D. thelypteris v. **pubescens** (Lawson) Nakai
Bot. Mag. Tokyo 45: 97. 1931.

Festuca obtusa Spreng. to
F. obtusa Biehler
Rhodora 47: 199. 1945

Festuca octoflora Walt. to
Vulpia octoflora (Walt.) Rydb.
Rhodora 47: 107. 1945

Festuca octoflora v. tenella (Willd.) Fern. to
Vulpia octoflora v. **tenella** (Willd.) Fern.
Rhodora 47: 107. 1945

Agropyron trachycaulum (Link) Malte
in Flora as synonymn of
A. subsecundum (Link) Hitchc. change to syn. of
A. **pauciflorum** (Schwein.) Hitchc.
Hitchcock, Man. Grasses, p. 775

Sporobolus clandestinus (Spreng.) Hitchc. to
S. **clandestinus** (Biehler) Hitchc.
Rhodora 47: 198. 1945

Cyperus densicaespitosus Mattf. & Kukenth.
(Kyllingia pumila of "Flora") to
C. **tenuifolius** (Steud.) Dandy
Rhodora 47: 113. 1945

Scirpus eriophorum Michx. to
S. **rubricosus** Fern.
Rhodora 47: 124. 1945

Juncus dudleyi Wieg. to
J. **tenuis** v. **dudleyi** (Wieg). Hermann
Jour. Arnold Arboret. 25: 56. 1944

Juncus macer S. F. Gray to
J. **tenuis** Willd.
Rhodora 47: 117. 1945

Juncus macer f. anthelatus (Wieg.) Hermann to
J. **tenuis** f. **anthelatus** (Wieg.) Hermann
Rhodora 47: 117-123. 1945
Castanea 10: 23. 1945

Juncus macer f. discretiflorus Hermann to
J. **tenuis** f. **discretiflorus** (Hermann) Fern.
Rhodora 47: 123. 1945

Juncus macer f. williamsii (Fern.) Hermann to
J. **tenuis** f. **williamsii** (Fern.) Hermann
Rhodora 47: 117-123. 1945
Castanea 10: 23. 1945

Populus deltoides Michx. to
P. deltoides Marsh.
Rehder, Trees and Shrubs, 2ed. p. 81, 1940

Ulmus americana L. to
U. americana f. alba (Ait.) Fern.
U. americana f. intercedens Fern.
U. americana f. laevior Fern.
U. americana f. pendula Fern.
Rhodora 47: 132. 1945

Ulmus fulva Michx. to
U. rubra Muhl.
Rhodora 47: 203. 1945

Rumex brittanica L. to
R. orbiculatus Gray
Rhodora 47: 133-137. 1945

Amaranthus graecizans L. to
A. albus L.
Rhodora 47: 139-140. 1945

Amaranthus bliotoides S. Wats. to
A. graecizans L.
Rhodora 47: 139-140. 1945

Sassafras Nees to
Sassafras Trew.
Amer. Midland Nat. 33: 500. 1945

Barbarea vulgaris v. arcuata (J. & C.) Fries.
(Indiana Plt. Distr. Record IV 1943) to
B. vulgaris v. arcuata (J. & C. Presl) Fries.
Rhodora 45: 304. 1943

Amorpha canescens Nutt. to
A. canescens Pursh
Pursh Fl. Amer. Sept. 2: 467. 1816

Rhus copallina L. to
R. copallina v. latifolia DC.
DC. Mon. 4: 384. 1883
Rhodora 37: 167-168. 1935

Rhus glabra v. borealis Britt. to
X R. borealis Greene
Amer. Midland Nat. 33: 498. 1945

Rhus pulvinata Greene to
X R. borealis Greene
Amer. Midland Nat. 33: 498-499. 1945

Rhus typhina L. to
R. typhina Torner
Amer. Midland Nat. 33: 499-500. 1945
Missouri Bot. Gard. Ann. 24: 326. 1937

Evonymus L. to
Euonymus L.
Amer. Midland Nat. 33: 511. 1945

Napaea dioica L. to
N. dioica v. **stellata** Fassett
Torreya 42: 179. 1943

Epilobium coloratum Muhl. to
E. coloratum Biehler
Rhodora 47: 199. 1945

Epilobium densus Raf.
(E. rosmarinifolium Pursh of Indiana Plt. Distr. Record V. 1944) to
E. leptophyllum Raf.
Rhodora 46: 382. 1944

Panax quinquefolium L. to
P. quinquefolius L.
North Amer. Flora 28B: 9. 1944

Panax trifolium L. to
P. trifolius L.
North Amer. Flora 28B: 10. 1944

Cornus stricta Lam. to
C. femina Willd.
Rhodora 47: 101, 168. 1945

Isanthus brachiatus (L.) BSP. to
Trichostema brachiatus L.
Brittonia 5: 289-291. 1945

Scutellaria incana Spreng. to
S. incana Biehler
Rhodora 47: 199. 1945

Scutellaria leonardi Epling to
S. parvula v. **leonardi** (Epling) Fern.
Rhodora 47: 172. 1945

Scutellaria ovalifolia Pers.
(S. ovalifolia v. hirsuta (Short) Fern. Indiana Plant Distr. Record IV. 1943) to
S. elliptica v. **hirsuta** (Short) Fern.
Rhodora 47: 201. 1945

Scutellaria nervosa Pursh to
S. **nervosa** v. **calvifolia** Fern. and
S. **nervosa** v. **typica** Fern.
Rhodora 47: 174. 1945

Monarda bradburiana Beck to
M. **russeliana** Nutt.
Rhodora 46: 491. 1945

Ruellia caroliniensis (Walt.) Steud. and
R. caroliniensis v. parviflora (Nees) Blake to
R. **caroliniensis** v. **cheloniformis** Fern.
v. **dentata** (Nees) Fern.
v. **membranacea** Fern.
v. **nanella** Fern.
v. **semicalva** Fern.
v. **typica** Fern.
R. **humilis** v. **calvescens** Ferns.
v. **expansa** Fern.
v. **frondosa** Fern.
v. **typica** Fern.
Rhodora 47: 1-38, 47-63, 69-90. 1945

Solidago glaberrima Martens to
S. **missouriensis** v. **fasciculata** Holz,
Amer. Midland Nat. 33: 250. 1945
U. S. Natl. Herb. Contr. 1: 208. 1892

Solidago graminifolia (L.) Salisb. to
S. **graminifolia** v. **typica** Rosendahl & Cronquist
Amer. Midland Nat. 33: 253. 1945

Solidago hispida Muhl. to
S. **hispida** v. **typica** Rosendahl & Cronquist
Amer. Midland Nat. 33: 248. 1945

Solidago nemoralis Ait. to
S. **nemoralis** v. **typica** Rosendahl & Cronquist
Amer. Midland Nat. 33: 249. 1945

Solidago nemoralis v. longipetiolata Palmer & Steyermark to
S. **nemoralis** v. **decemflora** (DC.) Fern.
Amer. Midland Nat. 33: 249. 1945
Rhodora 38: 226. 1936

Solidago speciosa Nutt. to
S. **speciosa** v. **typica** Rosendahl & Cronquist
Amer. Midland Nat. 33: 248. 1945

Antennaria plantaginifolia (L.) Richards to
A. **plantaginifolia** (L.) Hook.
Rhodora 47: 240. 1945

Eclipta alba (L.) Hassk. to
E. prostratus (L.) L.
Rhodora 47: 196-197. 1945

Artemisia gnaphalodes Nutt. to
A. ludoviciana v. latifolia (Bess.) T. & G.
Rhodora 47: 252-253. 1945

Lactuca canadensis v. typica Wieg. to
L. canadensis v. longifolia (Michx.) Farwell
Rhodora 40: 480-481. 1938

Lactuca canadensis v. integrifolia (Bigel.) Gray to
L. canadensis L.
Rhodora 40: 480-481. 1938

Lactuca campestris Greene to
L. ludoviciana f. campestris (Greene) Fern.
Rhodora 40: 481. 1938

State Flora Committee:
CHARLES C. DEAM, *Chairman*
RALPH KRIEBEL
T. G. YUNCKER
RAY C. FRIESNER, *Secretary*

CHEMISTRY

Chairman: C.W. HOLL, Manchester College

Professor Ed F. Degering, Purdue University, was elected chairman of the section for 1946.

Synthesis and Reactions of Ketenes*

WILLIAM A. ALLEN with ED F. DEGERING, Purdue University

A recent study by Gwynn and Degering[1] has shown, for the first time, that many ketones react with ketene in the presence of concentrated sulfuric acid, and in each case the product was found to be the acetate of the enol form of the specific ketone employed. These workers studied the reaction of ketene with many ketones, and made a very detailed investigation of the reaction of ketene with acetone.

The subject of the present investigation is a study of the reaction of ketene with 2-butanone, using sulfuric acid as a catalyst. Optimum conditions for this condensation are presented.

Experimental

Materials Used. The acetone used for the generation of the ketene was obtained from Carbide and Carbon Chemicals Corporation and was over 99 per cent pure.

The methyl ethyl ketone used for the condensations with ketene was supplied by the Shell Chemical Company and had a boiling range of 79°C. to 80.5°C. This material was not subjected to further purification.

The sulfuric acid, used exclusively as a catalyst in this work, was the technical grade (66° Baume in every case), and was obtained from various sources.

Pyrolysis and Condensation. The ketene generator was constructed substantially as described by Hurd[2] and modified by Gwynn[1]. In order to remove the unreacted acetone from the gaseous mixture, the pyrolytic products were conducted first through two water-cooled condensers, and then through two cold traps, the first of which was maintained at 0° C. and the second at —35°C. to —40°C. The resultant, substantially acetone-free, gas was then run into the material with which the desired reaction was to be effected. This introduction was facilitated by means of a small inlet tube which directed the entering gases into the blades of a rapidly revolving stirrer which served to disperse the material into

* Based upon a thesis submitted by William A. Allen to the faculty of Purdue University in partial fulfillment of the requirements for the Degree of Master of Science, May, 1942.

[1] Gwynn, B. H. and Degering, Ed. F., Condensation Products of Ketene with Ketones, J. Am. Chem. Soc., **64**, 2216 (1942).

[2] Hurd, J. Org. Chem., **5**, 122 (1940).

minute bubbles. The reaction tube was raised to the desired temperature by means of an externally heated oil-bath. An expansion chamber surrounded by an ice-bath was placed in a convenient position to return volatile liquids to the reaction chamber. The output of the generator was approximately 0.25 mole of ketene per hour. All analyses of products were made on a modified Podbielniak-type fractionating column, and the 2-buten-2-yl acetate obtained in this manner checked with the constants previously reported.[1]

Discussion

The reaction of ketene with 2-butanone was investigated for the purpose of determining optimum conditions for this condensation. The product, 2-buten-2-yl acetate, was previously prepared by Gwynn and Degering,[1] who condensed ketene with methyl ethyl ketone in the presence of sulfuric acid as a catalyst, and obtained a product which they

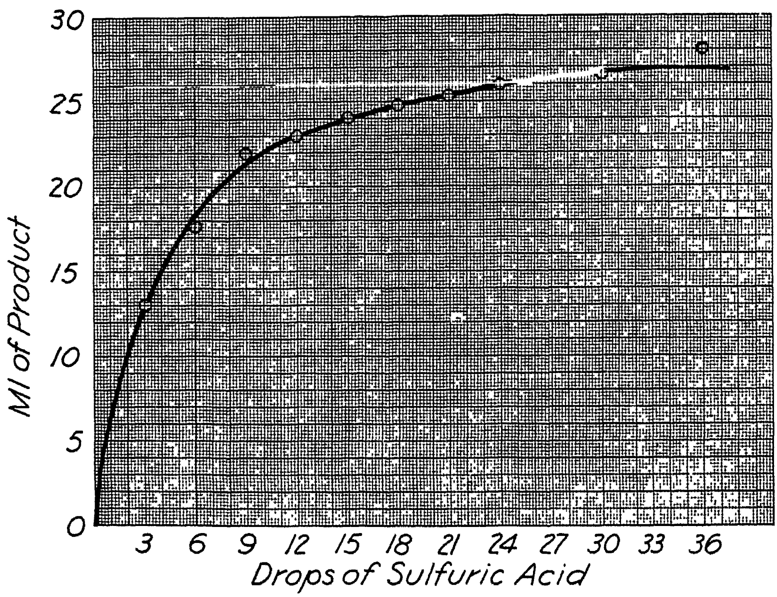

Figure 1

identified by several methods, including the determination of a saponification equivalent of the unsaturated ester and the formation of a 2,4-dinitrophenylhydrazone of the ketone obtained upon hydrolysis of the product. No attempt was made to determine the relative amounts of isomers obtained from this reaction.

According to expectation, a certain amount of ketene polymerization accompanies this reaction.

In determining the effect of catalyst concentration, the reaction time and reaction temperature were arbitrarily set at three hours and 75°C., respectively. The effect of varying the catalyst concentration is shown by Figure 1. Optimum results were obtained with a concentration of

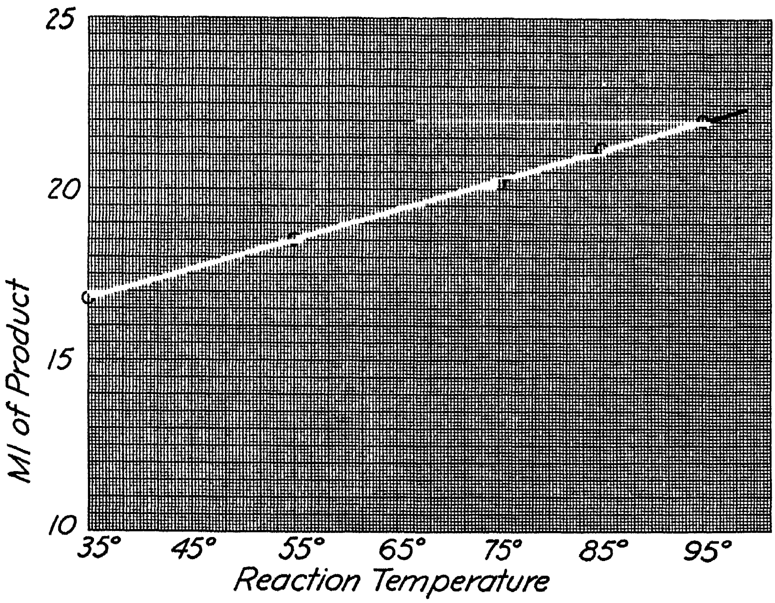

Figure 2

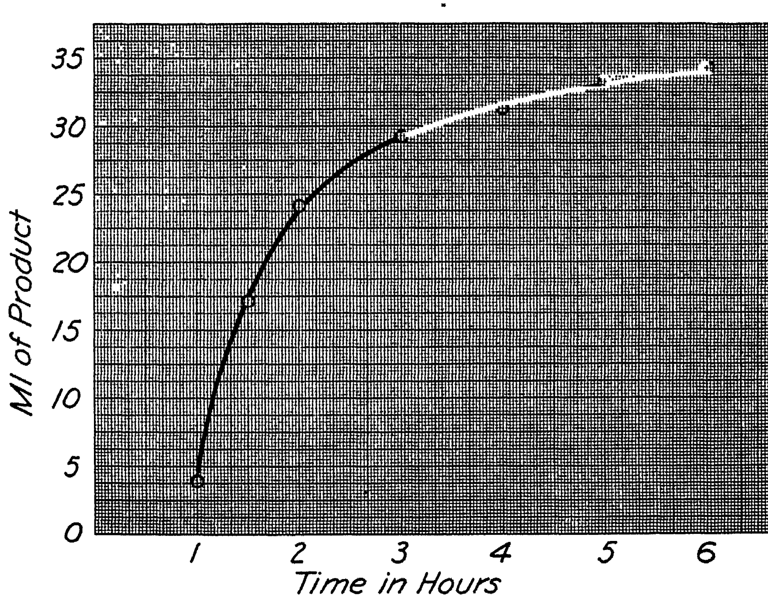

Figure 3

0.009 mole of sulfuric acid for each mole of 2-butanone. This optimum value may be calculated from Figure 1, which indicates that, under the experimental conditions, fifteen drops (0.5 milliliter) of sulfuric acid is the desired amount.

The effect of varying the bath temperature is shown by Figure 2. It will be seen that as the temperature is increased the yields of 2-buten-2-yl acetate are progressively increased, but due to operational difficulties which arise above 75°C., this temperature is taken to be optimum under the prevailing experimental conditions.

Figure 3 shows the effect of increasing the amount of ketene added to a given amount of methyl ethyl ketone. The amount of product increases quite rapidly for a time and then tends to approach a constant value. This fact may be brought about by a decrease in concentration of the methyl ethyl ketone which accompanies its utilization in the reaction. The optimum length of time for ketene passage was found to be approximately four hours, thus giving a value of one mole of ketene passed into the reaction mixture for 0.784 mole of methyl ethyl ketone employed.

Summary

A study has been made of the reaction between ketene and butanone to yield 2-buten-2-yl acetate. The optimum conditions determined for the reaction, as carried out on a batch scale, are with a rate of flow of 0.25 mole per hour of ketene through 0.784 mole of butanone in the presence of 0.007 mole of sulfuric acid at a temperature of 75°C. The conversion is about 39 per cent. No attempt was made to re-cycle the ketene and thus determine the overall yield. The polymerization of ketene is decreased by increasing the temperature of operation. Sulfuric acid was the most effective of the catalysts studied. The conversion of the butanone to 2-buten-2-yl acetate increases with the reaction time.

The Nitrogen Dioxide Oxidation of Starch*

J. W. MENCH, with ED F. DEGERING, Purdue University

Although the literature contains over two hundred references to the oxidation of starch, little is known concerning the structures of the products because various oxidants may simultaneously attack one or more of the hydroxl groups to produce a complicated structure containing carboxyl, aldehyde, and ketone groupings. An exception appears to result when periodic acid is used, since this oxidant seemingly exhibits a specificity towards parts of the carbohydrate molecule containing adjacent, secondary hydroxyl groupings.[1,2] The observations of Unruh, Yeckel, and Kenyon,[3,4] that cellulose can be oxidized with nitrogen dioxide to a polyanhydroglucuronic acid, indicate that this reagent preferentially attacks the primary hydroxyl groups in certain glycosides.

We have attempted to apply to starch both the static and cyclic method of oxidation reported by these men, in an effort to produce the *alpha*-linked polyanhydroglucuronic acids. However, the tendency of the powdered carbohydrate to pack made these procedures unsatisfactory, since the reactions were difficult to control and at least partial hydrolysis of the starch frequently occurred.

We have found, however, that under suitable conditions, starch may be oxidized by nitrogen dioxide to produce a new type of oxidized starch containing, predominately, uronic acid residues. This point was confirmed, qualitatively, by a positive *beta*-naphthol test,[5] which indicated the presence of glucuronic acid, although attempts to hydrolyze the products to glucuronic acid, and to prepare the cinchonine salt or oxime of this compound were without success.

The procedure and diluent utilized in this work was suggested by the work of Maurer and Drefahl,[6] who oxidized galactose, methyl glucoside, and methyl galactoside with nitrogen dioxide in carbon tetrachloride or chloroform—obtaining mucic acid and the corresponding substituted uronic acids, respectively. The method of oxidation is readily controlled so that oxidized starches of any desired carboxyl contents can be produced.

In marked contrast to the behavior of untreated starch, these products, even those with low carboxyl contents, do not dissolve in hot water. Since these products, presumably, exist as the free acids or as lactones, this would indicate that the carboxyl group is less water-solubilizing than is the primary hydroxyl grouping or considerable lactone formation has occurred, although nitrogen dioxide-oxidized celluloses show enhanced water-susceptibility with increasing carboxyl contents.[4] On the other hand, samples containing even small amounts of carboxyl groupings are

* This is an abstract of a portion of a thesis submitted by J. W. Mench to the Faculty of Purdue University in partial fulfillment of the requirements for the Degree of Doctor of Philosophy, June, 1944. American Maize-Products Co. fellow 1941-44. Present address, Eastman Kodak Company, Rochester, New York.

completely soluble in dilute, aqueous alkalies, and concentrated solutions of the alkali metal salts of these products do not retrograde upon cooling as do dispersions of untreated starch.

Premilinary work has indicated that some of the salts of these polyanhydroglucuronic acids might find application in the replacement of certain other modified starches and polyanhydrouronic acids as thickeners, gel-formers, dispersants, and stabilizers. The free acids have possible use as acidulants, dispersants, and disintegrates in certain food and medicinal products, and as a source of glucuronic acid.

Glucuronic acid, in turn, is a useful intermediate for the preparation of saccharic acid by the further oxidation with halides, electrolytically-generated halogens, or chlorous acids.[7] The production of *D-arabo*-trihydroxyglutaric acid from this intermediate is also feasible.[8] A further commercial application of glucuronic acid would be in the synthesis of ascorbic acid by methods analogous to those recently divulged by Regna and Caldwell[9] and Isbell.[10]

Experimental

All of the oxidations were conducted on a commercial grade of air-dried corn starch[11] which was given an additional 24 hour drying treatment in a vacuum oven at 55°C. and at a pressure of 10 mm. of Hg before use. The nitrogen dioxide employed was a commercial, Du Pont product, and the term refers to the equilibrium mixture of nitrogen dioxide and nitrogen tetroxide.

The apparatus consisted of a 250 ml. three-neck flask fitted with an efficient, rapid stirrer and a six-inch, spiral type reflux condenser. In all cases, 16.5 g. of starch was oxidized, which is equivalent to 0.1 mole when the residual moisture is taken into account. The diluent selected for the reaction was carbon tetrachloride, and it was usually used in the amount of 150 ml., although smaller amounts were also tested in order to determine the effect of higher initial concentrations of the oxidant. The nitrogen dioxide addition was facilitated by the use of a water-jacketed burette, the weight of the oxidant being calculated from density and temperature data.

All reactions were run at room temperature (25° to 29°C.), and after the desired time of oxidation, the products were filtered off on a Pyrex fritted-glass funnel, washed with carbon tetrachloride, and the excess solvent allowed to evaporate into the atmosphere. The oxidation products were then washed thoroughly with distilled water until the washings were free of acidity, followed by successive washings with acetone and ether. The latter solvent was allowed to evaporate, and the products were then given a more thorough drying over phosphorous pentoxide in a vacuum desiccator. The washing treatment just described completely removes all soluble materials such as excess oxidant or nitric acid, glucose, dextrins, or the organic acids which might be present because of partial hydrolysis and oxidation of the hydrolysis products of the starch.

The weight of oxidized starch obtained was always at least as great as the weight of starch used, and in the more highly oxidized samples, was usually somewhat greater.

Analysis of the Products:

The carboxyl contents of the products were determined by titration with standard alkali, as suggested by Unruh and Kenyon.[3] Although this is not as accurate as the method involving carbon dioxide evolution resulting from decarboxylation of the uronic acid residues, it was felt to be sufficiently accurate for comparison purposes. On oxidized celluloses, the method gives somewhat lower values than the carbon dioxide evolution method, especially at low carboxyl values, although it approaches the true value at the theoretical 25.5 per cent carboxyl content.

The method as used consisted in weighing 1 g. samples of the dried, oxidized starches into 250 ml. Erlenmeyer flasks, adding 30 ml. of 1 to 2 pyridine-water mixture, and heating on a steam bath until the samples were substantially in solution. The sides of the flasks were then washed down with 30 ml. of distilled water, and the contents titrated to a phenolphthalein end point with N/2 sodium hydroxide. The values obtained were corrected for by a blank titration on the solvent mixture.

Data:

Pertinent data and the results obtained are summarized in Table 1, and Figures 1, 2, 3, and 4 illustrate the relationships existing between

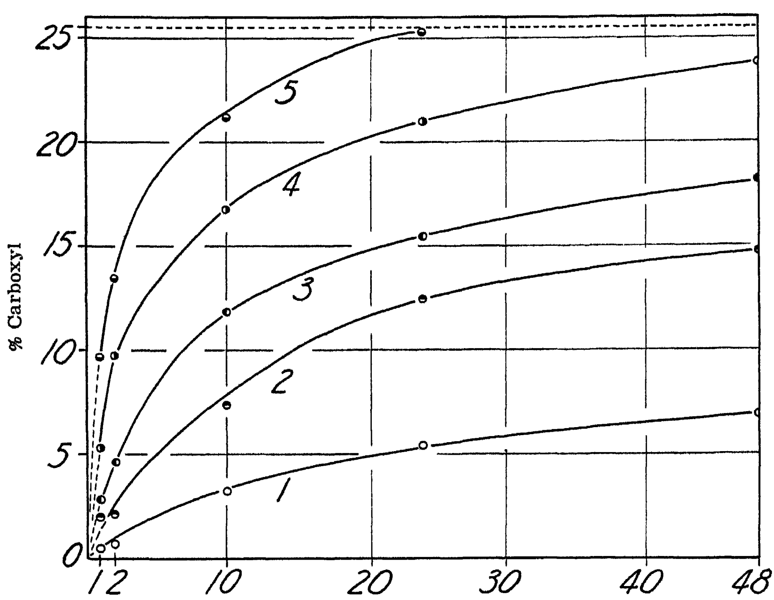

Fig. 1. The Relationship of Carboxyl Contents to the Time of Reaction at Various Ratios of Nitrogen Dioxide to Starch. Legend: Molar Ratio of Nitrogen Dioxide to Starch, 1. 1 to 1; 2. 2 to 1; 3. 3 to 1; 4. 5 to 1; and 6. 10 to 1.

the carboxyl contents of the products and some of the factors influencing the same.

Discussion:

A study of the data given in Table 1 and Figures 1 to 4 indicates that the reaction between nitrogen dioxide and starch is influenced by at least several factors:

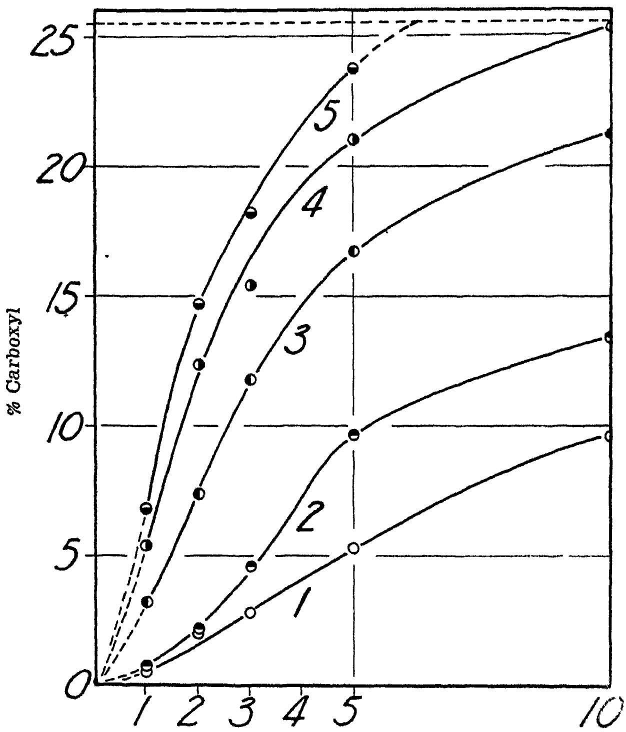

Fig. 2. The Relationship of Carboxyl Contents to the Ratio of Nitrogen Dioxide to Starch at Various Reaction Times. Legend: Reaction Time, 1. 1 hr.; 2. 2 hrs.; 3. 10 hrs.; 4. 24 hrs.; and 5. 48 hrs.

1. At a given molar ratio of oxidant to starch, the carboxyl content of the product is a function of the time of oxidation, increasing with the length of time of reaction. As shown in Fig. 1, the nitrogen dioxide rapidly oxidizes the starch in the early stages of the reaction, and then oxidation slows considerably. This may be due to loss of a portion of the oxidant through the reflux condenser and stirrer bearings over a long period of time, although the same effect was observed by Yackel and Kenyon[4] in their static cellulose oxidations, which were conducted in sealed containers.

2. At a given time of oxidation, the carboxyl content of the product is a function of the molar ratio of oxidant to starch, increasing as the

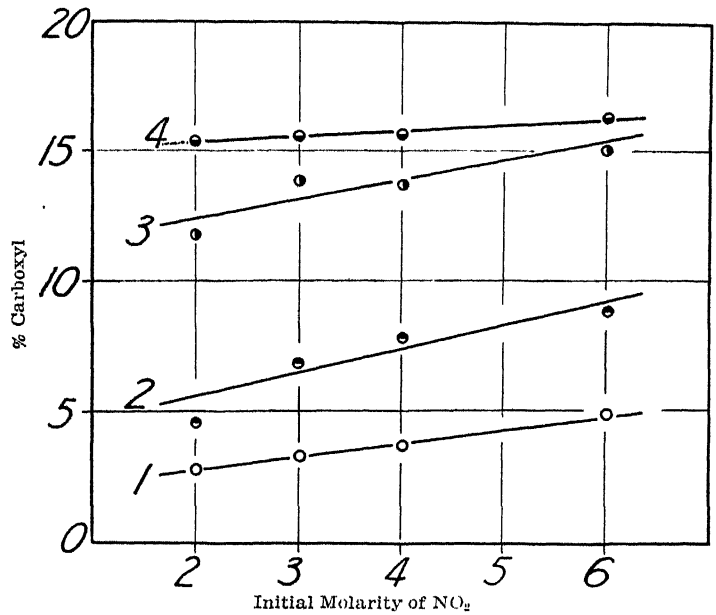

Fig. 3. The Relationship of Carboxyl Content to the Initial Molarity of Nitrogen Dioxide at Various Reaction Times. Legend: Reaction Time, 1. 1 hr.; 2. 2 hrs.; 3. 10 hrs.; and 4. 24 hrs.

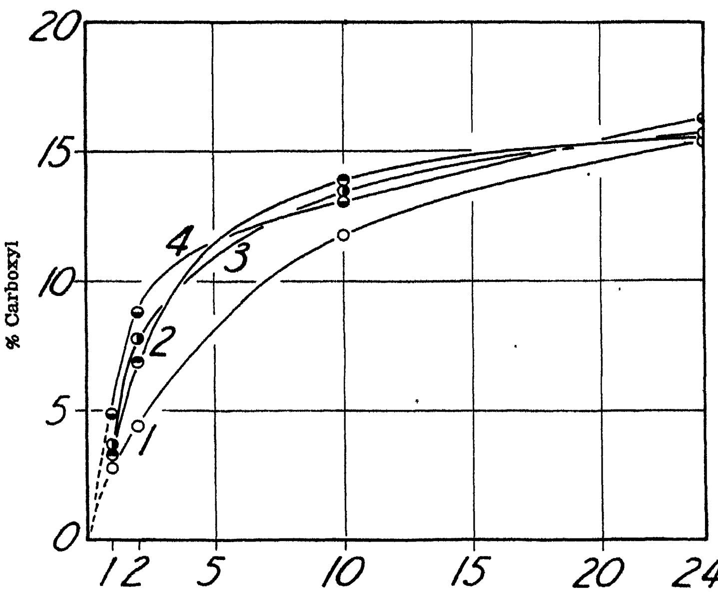

Fig. 4. The Relationship of Carboxyl Contents to the Time of Reaction at Various Initial Molarities of Nitrogen Dioxide. Legend: Initial Molarity of NO_2, 1. 2 *M*; 2. 3 *M*; 3. 4 *M*, and 4. 6 *M*.

molar ratio of the oxidant is increased. This effect is illustrated in Fig. 2.

It was thought that an increase in the initial concentration, or molarity, of the nitrogen dioxide might have the effect of increasing the carboxyl content without the use of large excesses of oxidant. This was tested by arbitrarily choosing an oxidant to starch ratio of 3 to 1, which is somewhat over the theoretical ratio of 2 to 1 required for the conversion of a primary hydroxyl group to carboxyl, and decreasing the amounts of carbon tetrachloride used as diluent. The results of these experiments, however, (cf. Fig. 3) indicate that at a given molar ratio (3 to 1) of oxidant to starch, and at a given time of oxidation, the carboxyl content of the product increases only slightly with an increase in the initial concentration of the oxidant. This effect is further illustrated in Fig. 4, in which carboxyl content has been plotted against the time of reaction at constant values of initial oxidant molarity. These curves almost coincide, with the exception of the one run at the lowest concentration (2.0 molar).

Properties of the Products:

One of the most surprising properties of these oxidized starches, even those with comparatively low carboxyl contents, is their insolubility in hot water. This is in marked contrast to the behavior of untreated starch, which is easily dispersed at elevated temperatures. All of the products, however, dissolve readily, when warmed, in dilute bases such as 2 per cent sodium hydroxide, 2 per cent sodium carbonate, dilute ammonium hydroxide, aqueous solutions of quaternary ammonium hydroxides such as Triton B, and aqueous pyridine. They are also soluble in 5 per cent sodium bicarbonate, liberating carbon dioxide from the solution. Unlike untreated starch, these products do not retrograde when fairly concentrated solutions containing their salts are cooled. The free salts may be obtained by precipitation of their aqueous solutions with ethanol or other water-miscible solvents, but the free acids are not easily regenerated by rendering the solutions acidic. This suggests that the uronic acid residues are hydrolyzed with ease.

As is the case with oxidized celluloses,[4] salts of other metals may be readily prepared by treatment of the oxidized starches with aqueous solutions of the metal acetates, since the polyanhydroglucuronic acid is strong enough to displace acetic acid from its salts. Polyvalent cations, as in the case of oxidized celluloses, yield water-insoluble salts.

Acknowledgment

The authors wish to express their sincere appreciation to the American Maize-Products Company and to its Director of Research, Dr. H. H. Schopmeyer, for the generous provision of funds, in the form of a fellowship, which made this and other research possible.

Summary

1. A method for the oxidation of starch with nitrogen dioxide is described, which results in the production of *alpha*-linked polyanhydroglucuronic acids. The oxidation is readily controlled to yield products of any desired carboxyl content.

2. The carboxyl content of the product is dependent, mainly, on the time of oxidation and the molar ratio of oxidant to starch, whereas the initial concentration of the nitrogen dioxide seems of less importance.

3. Methods of preparation of various salts of the oxidized starches are described.

4. The properties of the oxidized starches, and of their salts, have been described, and uses based on these are suggested.

Table 1. The Oxidation of Starch with Nitrogen Dioxide

Run	Molar ratio: NO_2/starch	Ml of CCl_4	Initial Molarity of NO_2	Time of Oxidation (hours)	Yield of washed product (grams)	% COOH
1	1	150	0.67	1	16.20	0.5
2	1	150	0.67	2	16.60	0.7
3	1	150	0.67	10	16.90	3.2
4	1	150	0.67	24	17.40	5.4
5	1	150	0.67	48	17.72	6.9
6	2	150	1.33	1	16.50	2.0
7	2	150	1.33	2	16.92	2.1
8	2	150	1.33	10	17.36	7.4
9	2	150	1.33	24	17.12	12.4
10	2	150	1.33	48	16.70	14.7
11	3	150	2.00	1	16.30	2.8
12	3	150	2.00	2	16.80	4.6
13	3	150	2.00	10	18.46	11.8
14	3	150	2.00	24	17.28	15.4
15	3	150	2.00	48	16.68	18.2
16	3	100	3.00	1	17.43	3.3
17	3	100	3.00	2	17.79	6.9
18	3	100	3.00	10	18.25	13.9
19	3	100	3.00	24	18.34	15.6

Run	Molar ratio: NO_2/starch	Ml of CCl_4	Initial Molarity of NO_2	Time of Oxidation (hours)	Yield of washed product (grams)	% COOH
20	3	75	4.00	1	17.90	3.7
21	3	75	4.00	2	17.68	7.8
22	3	75	4.00	10	19.56	13.7
23	3	75	4.00	24	18.34	15.7
24	3	50	6.00	1	18.40	4.9
25	3	50	6.00	2	18.23	8.8
26	3	50	6.00	10	18.38	15.1
27	3	50	6.00	24	18.45	16.3
28	5	150	3.33	1	17.36	5.3
29	5	150	3.33	2	17.87	9.7
30	5	150	3.33	10	19.12	16.7
31	5	150	3.33	24	18.59	21.0
32	5	150	3.33	48	17.72	23.8
33	10	150	6.67	1	18.15	9.6
34	10	150	6.67	2	18.60	13.4
35	10	150	6.67	10	19.13	21.2
36	10	150	6.67	24	18.85	25.3

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GEOLOGY and GEOGRAPHY

Chairman: E. R. SMITH, DePauw University

Professor G. D. Koch, Indiana State Teachers College, Terre Haute, was elected chairman of the section for 1946.

The Cataract Falls sandstone of the Ste. Genevieve formation in Southwestern Indiana. CLYDE A. MALOTT, Indiana University.—In and about the double falls of Mill Creek near Cataract, Owen County, Indiana, more than 100 feet of Mississippian strata are well exposed, revealing all of the Ste. Genevieve formation, on top of the St. Louis limestone below, and two or more Chester formations at the top. The upper Cataract falls is over a massive, fine-grained, calcareous sandstone at least 23 feet thick which occupies nearly the middle one-third of the Ste. Genevieve formation of 76 feet in thickness as exhibited in and near the two falls. Above the sandstone are 22 feet of Ste. Genevieve limestone up to the thin Aux Vases sandstone exposed a few feet above the dam near the upper falls. The lower Ste. Genevieve limestone at the lower falls is 30½ feet in thickness and rests unevenly on the St. Louis limestone about 10 feet above the plunge pool of the falls. Examination of the Ste. Genevieve at other localities both north and south of the Cataract falls reveals that the same sandstone is quite persistent, varying from one foot in thickness to more than 30 feet. This sandstone is probably the stratigraphic equivalent of the Rosiclare sandstone of southern Illinois, but its remoteness makes the correlation somewhat uncertain. The name *Cataract Falls sandstone*, here proposed, is quite appropriate for it in southwestern Indiana.

Iron and Steel Industries of Manchuria

MUZAFFER ERSELCUK, Purdue University

Although it would seem to the causal observer that little or no connection exists between Manchurian iron and steel and the state of Indiana, still there is a very definite link, the result of the perpetual motion of international trade. It will be remembered that Indiana is one of the larger producers of iron and steel. Naturally any developments in the iron and steel industry even in Manchuria, halfway around the world, will cause unmistakeable repercussions even in Indiana.

Since the Japanese occupation of Manchuria in 1931 striking developments have occurred in the expansion of Manchuria's iron and steel industry in the following phases:

1. Discovery of new deposits of raw materials for the production of iron and steel, especially of coal and iron ore.
2. Development of technology for utilizing low-grade iron deposits.
3. Modernization of the existing equipment and the building of new production facilities.

These were not the result of haphazard developments by private enterprise, but of methodical planning by the Japanese government, which wanted to insure a large supply of iron and steel for the constantly growing needs of industries in Japan proper. Naturally the important role of iron and steel in waging war was also kept well in mind. Japan was not alone in such activity, however; the development of iron ore and coal resources as well as the construction of blast furnaces and steel mills was being pushed at government expense during the decade preceding the Second World War in Russia, Germany, Italy, Poland, Rumania, Turkey, and Yugoslavia.

In 1929 the Manchurian production of iron ore and coal as well as of pig iron was exceedingly small, and no steel ingots or rolled steel were produced. During the first years of the Japanese occupation, there was a considerable increase in production of pig iron and its raw materials, but the large-scale expansion program did not start until 1937, as will be seen from the following figures:[1]

	In metric tons		
	1929	*1937*	*Goal for 1942*
Iron ore	986,000	2,257,000	12,000,000
Pig iron	294,000	739,000	4,860,000
Steel ingots	.	427,000	3,500,000
Rolled steel		370,000	2,000,000
Coal	10,024,000	12,540,000	38,000,000

[1] Schumpeter, E. B., et al., 1940. *The Industrialization of Japan and Manchukuo*, p. 388.

Raw Materials

Iron. Most of the known iron deposits in Manchuria are found in the southern and central regions of the country. In the north only small deposits have been discovered to date. The largest part of the Manchurian ores belong to the "Archean" type, which is credited with a possible two billion tons containing just under 35 per cent metallic iron. The ore body is found in an irregular linear zone stretching from the Sea of Japan coast of Northeastern Korea to Lunghsien in Hopeh, passing across Southern Manchuria and going under Liaotung Bay. Although the length of the ore zone is about 400 miles, the mineralized area is narrow.

In addition to the lean ores, in a few places localized pockets of rich ore containing 60 per cent or more metallic iron appear. At least 95 per cent of the ores, however, may be classified as poor, containing only 30-35 per cent metallic iron. On the basis of the most recent available data, the iron reserves of Manchuria may be estimated at over three billion tons, with a metallic content of 1.3 billion tons.

The important reserves are located in two areas, the Anshan-Waitoushan-Miaoerhkou triangle in Fengtien and the Tungpientao zone in Tunghua province. The former has a proved iron reserve of 1,168 million tons of lean ores and ten million tons of rich ores, or about 393 million tons of pure iron. The latter, not yet fully studied, is estimated to have reserves of about 1,500 million tons, with a fair proportion of high-grade ores. Besides these two areas, some iron is found in Central Manchuria, southeast of Hsinking.

On the basis of proved deposits, the production of pig iron at the rate of 5,000,000 tons annually can continue at least for another 200 years.

Coal. Geological investigations since 1932 have pushed estimates of coal reserves in Manchuria from 4,800 million to about 20,000 million tons.[2] Many other rich coal fields are anticipated as results of further surveys, raising the aggregate deposit figure still higher. In regard to thermal power and heat for steel furnaces and rolling mills, the coal supply is more than sufficient; however, only three groups of mines with aggregate known reserves of not more than 500 million tons of coal produce a high-grade metallurgical coking coal—that of Penhsihu in Fengtien, those of Tungpientao in Tunghua, and those of Mishan in Northeastern Manchuria. The total production capacity of these mines is about 2.5 million tons, much less than the requirements of the existing blast furnaces. To make conditions even worse, the Mishan mines, with a production capacity of about a million tons, are 650 miles away from the main blast furnace center of Anshan, and it is more advantageous from the point of transportation economy for the Mishan mines to ship coal to the Seishin blast furnaces in Korea rather than to Anshan. This leaves only about 1.5 million tons of coking coal for Manchurian blast furnaces, which therefore must import coking coal from North China.

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[2] Cressy, G. B., 1944. *Asia's Lands and Peoples*, p. 114.

Technology

Since most of the iron deposits in Manchuria are low-grade in nature, the Japanese scientists paid much attention to the beneficiation of iron ores. Since smelting costs rise rapidly with the higher amount of slag-forming constituents in the ore, and since Manchuria is already short in suitable smelting fuels, the beneficiation of iron ore was absolutely necessary, and it was inevitable that it should become an important part of the iron and steel industry.

Some of the beneficiation processes used in Manchuria were:

1. Anshan-type lean-ore-disposition process
2. Krupp-Renn process
3. Magnetic concentration
4. Flotation
5. High-frequency process.

Manufacturing facilities

Manchuria has four blast furnace centers: Anshan, Penhsihu, Mianohara, and Tungpientao.

Anshan. Plans were made in 1917 to construct a plant comprising eight blast furnaces, with a production capacity of one million tons. In 1919 the first blast furnace was completed and the second began operations a year later. It was soon discovered that the plant had been constructed without a careful examination of available raw materials. Attempts to use the low-grade ores in the vicinity of Anshan was unsuccessful because these ores are high in silicon content. Limestone had to be carried to the furnaces from a distance of 50 miles.

Continuous research solved the problems created by low-grade ores and the Anshan-type lean-ore-disposition method was patented. The concentration factory was completed in 1926.

After the conquest of Manchuria by the Japanese, the capacity of the existing furnaces was increased from 250 tons to 350 and a number of new furnaces were built. As a result, at the time of the Japanese surrender in August, 1945, the total capacity of the Anshan works was 2,781,000 tons of pig iron.

It was originally expected that coal from the huge, world-famous open pit mine at Fushun would be used as fuel, but it was later discovered that coal from Fushun does not produce a satisfactory metallurgical coke, and thus it was necessary to obtain coal from other collieries. Until 1942, Kaiping coals from Hopei were imported and mixed with Fushun coal in order to obtain a suitable coke. To augment the supply of coking coal the Japanese in 1943 completed a railroad across the Mongolian steppes and connected the Tatung coal mines in Suiyuan with Anshan. Incidentally, the same road carries high grade iron from the Lungyen mines in Chahar, which is mixed with enriched and lean ores from Anshan, Kyuchorei, and Waitoushan mines near Anshan and from the mines of the Kyowa Company in Central Manchuria.

The Anshan plants get their limestone from deposits at Kanchingtzu and Huolienchai, and magnesite and dolomite from Niuhsinshan. Fireclay is purchased from the Yentai coal mines.

The pig iron was for the most part converted into steel at Anshan. Some pig iron, as well as a large amount of steel ingots, were exported to Japan for further processing.

Penhsihu. This plant with two 250-ton furnaces was completed during the First World War. In 1939 it was decided to enlarge its capacity. The first new blast furnace was put into operation in December, 1940, and the other was completed in March, 1941, bringing the total capacity to 500,00 tons of pig iron a year.

Penhsihu occupies the most convenient position for the gathering of materials needed in the manufacture of pig iron. Large limestone deposits exist near Penhsihu, the product of which is transported directly to the limestone yard of the plant from the quarry by means of a mile-long aerial cable. The iron ore is shipped from the Miaoerhkow mine about 25 miles to the southwest. The main factor in locating the plants at Penhsihu, however, was the abundance of coking coal reserves, estimated at 190 million tons, which are found in the vicinity of the plants.

Mianohara. In order to utilize the cargo space of the empty railroad cars returning from Penhsihu after delivering their load of iron ore from the Miaoerhkow mines, it was decided to build a smelting plant at Mianohara, near the mines. The coking coal for this plant was to be shipped in from Penhsihu. The first blast furnace was put into operation in October, 1941, and another by the end of 1942. The new plant, which contains steel-making facilities, was to be in full operation by 1943.

The low-phosphorus pig iron produced at Mianohara and Penhsihu constitutes an essential raw material for manufacturing high-grade steel.

Tungpientao. The Tungpientao region has large deposits of coking coal and high-grade ore. The Tungpientao Company, which operates both the coal and iron mines, has two blast furnaces completed during 1942-43. The pig iron produced was exported to Japan.

Other plants. Besides the above-mentioned large units, there are three small plants engaged in the production of pig iron and sponge iron.

Conclusion

Political and military, rather than economic, considerations were responsible for the rapid growth of the iron and steel industry in Manchuria. As long as strategic factors determined the existence of such industries, large subsidies were available to maintain and operate them.

With the collapse of Japan, non-economic considerations have undergone a drastic change and the iron and steel industries of Manchuria as a whole do not have an economic foundation to stand upon. Therefore the question arises of their future.

Assuming that the Russians will not remove the installations and will maintain them in good condition, the new owners of these industries, the Chinese, will face two alternatives.

1. To let the unneeded capacity of the plants lie idle until the day Chinese industrialization will warrant their use.

2. To operate the plants and export the unneeded part of the production until the total production could be utilized in China. It is probable that the Chinese leaders would prefer this alternative. However, this means not only employing foreign technical help in order to manage the plants, but also paying large subsidies, a doubtful condition for the poor Chinese finances.

In conclusion, therefore, one may say that the Manchurian iron and steel industry probably will not furnish any serious competition to that of America in the international markets for some time to come.

Geologic Contrasts in Indiana State Parks

OTIS W. FREEMAN, Indiana University

The state parks of Indiana, with sites selected largely for scenic and historic reasons but partly with the intent to secure wide geographical distribution for recreational purposes, contain a fairly complete sequence of the geological formations outcropping in the state, besides providing examples for a large majority of the physiographic principles. Evidence of vulcanism is one of the chief things missing, since all of the exposed bedrock in Indiana is of sedimentary origin. Even so, many types of igneous and metamorphic rocks can be picked up among the glacial boulders in the northern part of the state.

The oldest exposed rocks are those of the Ordovician period. Excellent outcrops for the study of the Ordovician strata occur in southeastern Indiana on the west flank of the Cincinnati Arch. The beds are highly fossiliferous and one of the famous collecting grounds for the life forms of this period is near Madison.

Clifty Falls State Park includes strata classified in the upper Ordovician, the Silurian and base of the Devonian periods. The Silurian rocks occupy the hill slopes above the falls and inner gorges in the park with the Devonian capping the higher hills.

The Ordovician formations in the park area from the base upward, begin with 25 feet of the Bellevue, followed by 115 feet of the Arnheim, 55 feet of the Waynesville, 50 feet of the Liberty, about 32 feet of the Saluda and possibly 6 feet of Whitewater. Shale predominates from the Bellevue through the Liberty and is interbedded with thin layers and lenses of limestone, and in contrast the Saluda is a thick bedded limestone with reef corals occuring near its base. The Saluda resists erosion so that being underlain by the crumbly Liberty beds, the limestone forms a waterfall ledge in the streams that flow across it. Clifty, Little Clifty, Hoffman, Tunnel and other falls all have developed at the outcrop of the Saluda in the streambeds. Hanging Rock on Highway No. 7 near Madison is another good example of the ledge forming qualities of the Saluda limestone.

Clifty Falls has a vertical drop of about 50 feet in a total descent of 70 feet. It is easy to walk back of the falls and observe how the splashing and spray from the falling water along with other factors cause the weak Liberty formation to weather and erode thus creating a considerable niche. This process undermines the Saluda limestone and at intervals, perhaps of many years, a block breaks off. Since the first plunge developed from the cliffs at the edge of the Ohio Valley, the falls have retreated upstream leaving a steep, narrow gorge downstream. In all Clifty Falls has retreated about 11,000 feet and, separating from Clifty Creek, the various tributaries each have worn a gorge that ends in a waterfall. In addition to the work by running water and weather-

ing that largely account for the talus accumulations at the base of the cliffs, the work of ground water is shown through the presence of seeps, springs and small landslides.[1]

In 1897 Professor Glenn Culbertson of Hanover College described[2] preliminary work that he hoped would permit the approximate determination of the time required for the erosion of Clifty Falls. In 1911[3] he noted that in 14 years between 1897 and 1911 the undermining at Clifty Falls amounted to four and one-fourth inches. His son, J. A. Culbertson, found in 1927,[4] 30 years after the spike used for measurement was driven into the rocks behind the falls, that the mists had caused a total sapping equal to seven and one-eighth inches. This is about one-fourth of an inch per year for the 30 years. Assuming that the volume of water and rate of recession has been continuously at this rate, about half a million years would have elapsed since the falls began early in the Glacial epoch. Further studies here will be of interest.

The newly established state park near Versailles and the projected Whitewater Park southwest of Liberty in Union county are underlain by the shales of the Richmond (Upper Ordovician) group. However, the strata are not so well exposed or so extensive as in Clifty Falls State Park although including much the same beds. In part the rock outcrops are masked by superficial glacial deposits.

The next park in stratigraphical sequence is Muscatatuck State Park near Vernon. Here the surface formation is the New Albany shale of Devonian age. Below these beds, near the ruins of the Vinegar mill are around 60 feet of Devonian limestones (Beechwood, Jeffersonville, and Geneva), with the Louisville and shows of Waldron shale of Silurian age appearing near the banks of the river. Thus the base of the strata at Muscatatuck State Park coincides with the top beds at Clifty Falls State Park.

Tippecanoe State Park is primarily of historical interest, but, for the record, it may be mentioned that beneath a cover of glacial drift the bedrock of the area is the New Albany shale of Devonian age.

The older school of Indiana geologists called the sandstones and shales of lower Mississippian age, the Knobstone, naming the formation from the rounded hills that are developed from it by erosion. This formation extends from opposite Louisville northward through Lloyd, Washington, Jackson, Brown and eastern Monroe counties. The name Knobstone has been superseded by the name Borden, but anyone who has seen the peculiar looking conical knobs that erosion has developed from this formation will recognize how good a descriptive term Knobstone was. Stockdale[5] estimated that the Borden in southern Indiana has an areal extent of 1,880 square miles, and to vary in thickness from 400

[1] More about the geology of Clifty Falls State Park is given by the author in Outdoor Indiana, **12**, July, 1945, 10-11.

[2] Proc. Ind. Acad. Sci. 1897, 242-243.

[3] Proc. Ind. Acad. Sci. 1911, 169-170.

[4] Proc. Ind. Acad. Sci. 1927, **37**:118.

[5] Stockdale, Paris B., *The Borden Rocks of Southern Indiana*, Pub. No. 98, Dep't of Conservation, Indianapolis, 1931, p. 5.

feet at the Ohio River to double that in Brown County.[6] In central Indiana the Borden consists of sandstone and shale with occasional lenticular limestone beds. The famous Brown County scenery is all developed upon the Borden.

The Brown County State Park contains rocks of the Borden formation only. Erosion has not been deep enough to expose the underlying New Albany shale, and the overlying Harrodsburg limestone does not occur anywhere in Brown County. Stockdale reports 760 feet of Borden,[7] including subsurface, at Nashville close to the park. Sandstone members of the Borden are fairly resistant and account for the flatish summits of some of the ridges. Narrow ravines are common, and slumping by weak shales that lie under the sandstones help to maintain steep slopes to the hills. Numerous quartz geodes occur in certain horizons of the Borden strata. Some of the beds are quite fossiliferous. Bioherms, composed largely of crinoid stems, occur in the upper Borden. All of these features, along with examples of weathering and the work of water erosion can be seen in Brown County State Park. Although the State Park area was not invaded by glaciers, melt water from the ice sheet crossed Brown County and deposited gravel and silt. From the fire tower there is a superior view of the pre-Pleistocene dissected peneplain, correlated with the Highland Rim Peneplain of Kentucky and Tennessee, preserved in southern Indiana chiefly on the harder rock formations. The base of the fire tower is 1,060 feet in elevation above sea level and Salt Creek is 600 feet, giving a maximum difference in relief of 460 feet. The north lookout is 290 feet above the creek and Abe Martin Lodge is 160 feet.

Four Mississippian limestone formations lie above the Borden and have been named the Harrodsburg, Salem, St. Louis and St. Genevieve. Throughout south-central Indiana these limestones have been affected by solution from ground water that has resulted in numerous caves, sinkholes, lost rivers and other features of karst topography.[8] Among the caverns, Wyandotte and Marengo are best known, being famous for their curious stalactites and other deposits. Although privately owned, these caves are seen by thousands of visitors each year. Water-coursed caverns of considerable size are found in Spring Mill State Park, and the work of underground water is also important at McCormick's Creek State Park. The strata in both these parks that are especially subject to the formation of caves are the St. Louis and St. Genevieve limestones. The Salem limestone occurs below the St. Genevieve in both parks but is nearly devoid of bedding planes, is fairly soft and quite porous. These characteristics permit ground water to percolate through it easily so that the Salem is less readily dissolved to form caves. The Salem is the source of the Indiana limestone for building purposes, and in McCormick's Creek State Park near the White River is an old quarry which provided some of the stone used in constructing the state

[6] Stockdale, op. cit., pp. 56-62.

[7] Stockdale, op. cit., p. 62.

[8] Malott, C. A., Significant Features of the Indiana Karst, Proc. Ind. Acad. Sci., vol. 54:8-24, 1945.

capitol. In contrast, the Harrodsburg, St. Louis and St. Genevieve are rather dense and have many fractures, joints and bedding planes along which the water dissolves the limestone. Hence caves are scarce in the Salem and common in the other limestones mentioned.

An underground river flows through the caves in Spring Mill State Park, and the presence of blind fish in the cave water and the chance of a boat ride underground always interest visitors. The Spring Mill caves appear rather youthful as they are still in process of formation by solution and erosion. The deposition of calcite by dripping ground water, apt to occur in a mature stage in the life history of caves, has not yet been attained.

At McCormick's Creek State Park numerous sinkholes and springs, with some of the springs carrying the outflow from cavernous drainage, provide evidence of the work of ground water. As mentioned previously, the underground drainage is characteristic of the St. Louis and St. Genevieve limestones only. The maximum difference in relief in the park is 220 feet between White River and near Camp Friendly. The most spectacular feature of the park is the narrow gorge of McCormick's Creek that terminates with a drop of 65 feet between just above and just below the falls. The total drop of McCormick's Creek in its lower course is 160 feet in about two miles. Most of the gorge is believed to have been worn in post-glacial time. While the limestone bedrock has been an important factor in the development of the park scenery, the surface features of the area that includes the park, called the Flatwoods, have been modified by the continental glacier.

Siebenthal[9] and Malott[10] agree that the continental glacier crossed the White River and invaded the Mitchel Plain about two miles east of Spencer. The ice dammed the drainage into White River and formed a temporary lake in the Flatwoods area. A similar ponding occured in the valley of Bean Blossom Creek, and the water from these combined glacial marginal lakes overflowed southward to the west of Ellettsville and into Raccoon Creek according to Malott. With the disappearance of the ice the considerable descent of McCormick's Creek permitted that stream to secure most of the surplus water from the Flatwoods. This was favored by the underground drainage channels in the St. Louis limestone that helped to feed McCormick's Creek. In a way this capture of drainage is an example of underground piracy. The two mile long gorge in the State Park is considered by Malott to be largely post-glacial although he thinks the canyon may have been begun by underground drainage. The deep gorge seemingly was the result of the combined action of solution and possible collapse of the cave roof and of stream erosion, the latter being probably the more important factor.

The Chester formations, of upper Mississippian age, are composed of interbedded layers of sandstone, limestone and shale. Areally the Chester lies just west of the exposures of the cavernous Mississippian limestones just discussed. Erosion of the Chester has resulted in in-

[9] Siebenthal, C. E., 21st Ann. Rept., Ind. Geol. Surv., 1896, p. 302.
[10] Malott, C. A., 39th Ann. Rept., Ind. Geol. Surv., 1914, pp. 217-222.

teresting gorges, picturesque cliffs, wooded hills and sparkling waterfalls, fully as great in scenic interest as in some of the established state parks, but no park area includes any of the Chester formations. Perhaps in the future this will be changed, since the Chester possesses a zone of mineral springs, such as French Lick and West Baden in western Orange County, and Trinity and Indian springs in Martin County.

Two popular state parks are located where the surface bedrock belongs to the Pennsylvanian system, which contains the coal deposits of Indiana. Turkey Run State Park and the nearby Shades, a private recreational area, contain gorges carved from the Mansfield formation at the base of the Pennsylvanian. Shakamak State Park is located on strata belonging to the Petersburg formation, about 300 feet above the Mansfield stratigraphically.

The Mansfield consists mostly of a coarse and often cross-bedded sandstone but includes some beds of shale and generally a thin seam of coal toward its base. Cross-bedding is considered proof of the deposition of the Mansfield near or above sea level where shifting current's operated. The Mansfield is massive and resistant. Wherever the streams have cut valleys into bedrock, cliffs of sandstone rise almost vertically for 50 feet or more. In places Turkey Run gorge is not half as wide as it is deep. Numerous potholes, waterfalls, eratic boulders and fallen rocks are features of interest in addition to the wooded, overhanging cliffs. A fine virgin forest delights the nature lover. Springs at the base of the sandstone above a layer of impervious shale illustrate a common cause for this phenomena.[11]

Shakamak State Park is situated in a rather flat area with a difference of elevation within its boundaries of 85 feet, perhaps more than might appear to the visitor. Two artificial lakes occupy much of the principal valleys and cover some of the outcrops so that exposures of bedrock are uncommon. However, in one place a coal bed is exposed as an exhibit. In the vicinity of the park are some of the largest coal mines in the state. Some of the mines are operated through shafts, others are strip mines.

Northern Indiana is deeply covered by glacial drift and the surface features of the state parks there are of Pleistocene or Recent age. The kind and age of the bedrock under the glacial debris has no significance. Pokagon and Indiana Dunes are the most popular parks in this part of the state, but Tippecanoe, Mounds and Bass Lake Beach are also attractive.

Pokagon State Park on Lake James is a good example of a region deeply covered by drift, in places 500 feet thick, where lakes of glacial origin are abundant. Moraines, kames, kettleholes, outwash deposits, erratic boulders and other evidences of glaciation are everywhere. Both Lake James and Bass Lake are examples of glacial lakes.

In northern Indiana are three abandoned beaches and associated deposits formed by prehistoric, glacial Lake Chicago when it stood at

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[11] Freeman, O. W., *Geology and Turkey Run State Park,* Outdoor Indiana, 12, 12-13, August, 1945.

55, 35 and 20 feet above the present level of Lake Michigan. Sand dunes often are associated with the old beaches. The dunes of Indiana Dunes State Park are being formed at the present time, the needed sand being derived from glacial deposits eroded by the waves from the shores of Illinois and southern Wisconsin and Michigan. Currents carry the sand to the south end of Lake Michigan where it is washed on to the beach. After drying, the prevailing winds blow the sand inland and the process of dune formation begins. The dunes are of two principal types: fore dunes and blowout dunes. The fore dunes form at the edge of broad beaches on which sand is accumulating and are usually 20-50 feet high, but occasionally attain a height of 100 feet. Blowout dunes result when, after vegetation has stabilized the fore dunes, the cover is destroyed in some way and the wind blows the sand away to cut trenches through the older dunes and dump the sand to leeward. The resulting big active tongues of sand are the most spectacular feature of the park. Blowout dunes are the highest hills in the park, Mount Tom reaching 193 feet above the lake with Mount Holden and Mount Jackson rising nearly as high. In their advance the blowout dunes invade. the forest and kill the tress, cross marshes and may bury buildings or cover highways.[12]

The mounds in Mounds State Park near Anderson were built by Indians many centuries ago. Beneath a cover of glacial debris in a stream valley are exposures of the Niagara formation of Silurian age, but the outcrops of bedrock are of less interest than the constructions by prehistoric man.

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[12] For further information about the Indiana dunes consult: Cressey, George B., *The Indiana Sand Dunes and Shore Lines of the Lake Michigan Basin,* Geog. Soc. of Chicago, Bull. 8, 1928. Freeman, O. W. *Outdoor Indiana,* **12**, Sept. 1945, 12-13 and 16.

Needed, More Secondary School Geography

G. David Koch, Indiana State Teachers College

On December 7, 1941, America discovered geography. Since that catastrophic day, nearly four years ago, a renewed interest has developed in geography. During the war which ended recently our newspapers and magazines offered daily spectacular lessons of a geographic nature. Almost every home in the United States has a special interest in a place or places heretofore wholly unknown. With the war ended and peace conferences common happenings, we are beginning to realize that a "just peace" and a stable "world order" are securely bound up with a thorough knowledge of geography. Unless the geographic aspect of all problems that face the framers of peace are weighed carefully, any formal peace agreements will be fruitless.

Together with a renewed interest in geography as a nation, there is now underway a widespread movement for the reintroduction of geography into the secondary schools of the country. Courses of study and work programs are being arranged to meet the special demands and capacities of teachers and prospective teachers in the field of geography.

The inclusion of geography in the secondary school curriculum, and taught by teachers specially trained in that area, are timely and of paramount importance. Our young men and women are leaving high school with little or no training in geography. Their knowledge of the world, not to mention their own country, is unpardonable. Data compiled from over five hundred students enrolled in the introductory geography course at Indiana State Teachers College during the past five years indicates that slightly over one-fourth, or twenty-seven per cent, of these young people had received any instruction in geography during their secondary school training. Informal questioning of those students who had taken geography in high school further revealed that the courses were largely limited to physical or economic-commercial geography. In most cases the teachers of these courses were wholly untrained in geography, and quite likely, professed little or no knowledge nor any interest in the subject. Filling out exercises in a workbook and constructing graphs showing the corn production of Iowa or potato yield of Idaho comprised most of the work in such geography classes. It is little wonder that geography has been "shelved" and disregarded as meriting a permanent place in the secondary school curriculum.

Further evidence of the need for more geography came to light through place tests which were given to the same students mentioned above. The class is given an outline map of the United States and is required to locate the states as the instructor reads the individual states. Data indicates that only four per cent of the students located correctly all of the states. Forty-four per cent incorrectly paced at least 10

states, while twenty-seven per cent failed to locate correctly over one-half of the states.

The accompanying table shows, in percentages, the frequency with which the various states were incorrectly placed by the students. Only one state, Florida, was correctly placed by all students. Its location and shape, together with its importance as a winter resort, are largely responsible for it being well known. Texas was correctly located by all but one per cent of the students with California and Indiana being incorrectly placed by two per cent. The fact that a college freshman, and in one case a senior, incorrectly located their home state is certainly lamentable.

The state most frequently missed was Vermont with a per cent of error of seventy-three. New Hampshire and Nebraska followed closely, each being incorrectly located by sixty-six per cent of the students. It should be pointed out, however, that thirty-five per cent of those who missed New Hampshire and Vermont interchanged the two states. New Mexico and Arizona were frequently interchanged as were Alabama, Georgia and Mississippi. The frequency with which Nebraska, Kansas, Colorado and Wyoming were incorrectly located was due in no small degree to the same factor.

Further examination of Table I shows that only seven of the states were correctly located by at least ninety per cent of the students, ten were correctly located by eighty per cent, nineteen by seventy per cent, thirty by sixty per cent and thirty-nine by fifty per cent of the students.

It is, of course, admitted that the same results may not be obtained in other parts of the United States. Certainly the section of the country in which the tests are given would determine the distribution of errors. For example, should the test be given in Vermont, certainly that state would have been correctly located with almost one hundred per cent accuracy.

It is also admitted that location is only one phase of geography. However, it is an important phase and one that can be developed without a great amount of expensive equipment. The first step in the study of a city or a region is its location.

Tests similar to the one just described were also given but dealing with places of prominence in the Pacific theatre of war. Thirty-five per cent of the students were unable to locate at least one-half of the stations correctly. Only two students among the one hundred and eight who took the location test of the Pacific region were able to locate the twenty places correctly. These figures indicate a definite lack of awareness to locational geography in relation to current events and the future security of the world.

There needs to be, however, considerable caution exercised when stressing more geography in secondary schools. The average person's impression of the subject is too often unbalanced. Evidence of this is to be found in current magazines, newspapers and the mass of polar projections and "Air Age" maps now being published. The publications too frequently leave the impression upon those unacquainted with true georgraphy that new air routes, distances and times between one place

and another are the core of the subject matter. This is hardly what true geography has been or will be in the future.

Real geography is far more than a matter of names, and an understanding of flying time and directions. Geography concerns itself with all of those features, both physical and cultural, which affect man's adjustments to his natural surroundings. The continuous struggle of man to adjust his activities to climate, soil, and topography; to secure efficiently the natural resources of the land; to secure food, shelter and clothing; to find and hold markets and control trade routes; all are a part of geography and its significance in man's everyday life. The kind of surroundings leaves an indelible stamp upon the people who live in it.

Table I

The Frequency, in Percentage, with which the Various States were Missed by Students

State	Percentage	State	Percentage
Alabama	38	Nebraska	66
Arizona	57	Nevada	30
Arkansas	47	New Hampshire	66
California	2	New Jersey	46
Colorado	62	New Mexico	39
Connecticut	41	New York	29
Delaware	55	North Carolina	39
Florida	0	North Dakota	31
Georgia	29	Ohio	9
Idaho	36	Oklahoma	41
Illinois	5	Oregon	23
Indiana	2	Pennsylvania	26
Iowa	38	Rhode Island	41
Kansas	45	South Carolina	35
Kentucky	9	South Dakota	29
Louisiana	41	Tennessee	19
Maine	16	Texas	1
Maryland	57	Utah	40
Massachusetts	54	Vermont	73
Michigan	22	Virginia	36
Minnesota	30	Washington	14
Mississippi	44	West Virginia	38
Missouri	41	Wisconsin	28
Montana	35	Wyoming	52

Some Factors Which Enabled Europeans Successfully to Settle the American Forests

RICHARD G. LILLARD, Indiana University

To Europeans in the seventeenth and eighteenth centuries the eastern part of America was a wonderful forested "Eden newly sprung from the Ocean" yet at the same time a formidable challenge to exploration, conquest, and settlement. Most Europeans came from open countrysides and were poor men of the handicraft period when science and folklore were still much intermingled. But selecting from their total stock of knowledge, experimenting afresh, and learning from the natives, the colonists in time developed a complete system for survival in the forest and the setting up of civilization. American history entered a Wooden Age, when the forest was both major aid and major obstacle.

Travel and communication were a problem in the tangled primeval woods. Colonists solved the problem in part by using boats along the sunken Atlantic shoreline where bays and estuaries interfingered with the land, and along the big rivers that thrust into the continent toward the easy portages near the Great Lakes. They adopted the Indian dugout, made from whole tree trunks, and the canoe, made primarily of bark. When they had to travel by land they went afoot, following the elaborate network of Indian trails, or breaking trail, aided by Indian woodcraft. They crossed swollen streams by felling a tree across to make a "raccoon" bridge or by binding impromptu rafts with grapevines. While traders and soldiers found ways to use horses, emigrants used the European ox, which with its cloven feet was better adapted to pulling loads through marshes and among stumps and roots. Men learned to select routes by studying vegetation and soil and chopped out lanes, using blazes to indicate main and side roads. The corduroy road, made by laying logs side by side at right angles to the line of travel, became a commonplace road through bogs and bottoms.[1]

The backwoods developed a characteristic weapon, the long rifle. The musket of the early colonists, the Blunderbuss, and the Brown Bess were relatively useless. Short barreled and hard kicking, flaring at the muzzle, the musket was always inaccurate and short ranged and was therefore most effective when shot in volleys. Its days were numbered, for about the year 1500 Gaspard Kollner, a Viennese, had worked spiral grooves into the bore of a gun. By giving a rotary motion to the bullet, he gave it unprecedented distance and accuracy. The idea spread into Germany and Switzerland, where men formed corps of Jaeger rifle-

[1] Bartram, William, 1791. *Travels Through North and South Carolina.* Philadelphia; Belknap, Jeremy, 1813. *The History of New Hampshire,* Boston; Hall, B. R., 1855. *The New Purchase.* New York. The notes to this paper list only a few of the available sources.

men, and came with Protestant refugees to Pennsylvania. There backwoods smith experimented with bore, rifling, length of barrel, and native materials. By 1740 they had developed a native rifle weighing fourteen to twenty pounds, four to six feet long, with a stock of black walnut running clear to the muzzle. Fitted to the work of stalking the abundant game of the woods, it was relatively silent, economical in the use of lead and powder, light, strong, easily repaired, and—in a world of logs and branches—easily supported for aiming. It fed whole families and was essential in peace and war to all kinds of frontiersmen. At the start of the Revolution, which it helped win, exhibition shooters demonstrated its possibilities. At Lancaster a rifleman put eight consecutive shots into a two-inch bullseye sixty yards away. On Cambridge Common another rifleman hit a seven-inch pole 250 yards away.[2]

The leather shirt of the hunter, his moccasins, his habits in camping out, his lightweight nourishment of dried venison and cornmeal, his strategy in hunting wild animals, really a series of intrigues and ambushes—these came from Indian tutors. Applied to warfare against human beings, this whole pattern became the American style of fighting, of constant movement, applied woodcraft, surprise, and ambuscade, that European officers and soldiers had to master in order to survive.[3]

The most important task facing colonists was deforestation. They learned to select soil by noting the species of trees growing on it, the size and number. From the Indians they borrowed the technique of girdling trees, and they developed their own schemes for clearing land by felling and burning up the trees. While they developed many kinds of fences that used the abundant wood of the clearings, it was types of stake and rail fences, following patterns used in Sweden and the forested portions of central Europe, that came to dominate. The most notable was the Virginia worm fence, six to eight rails high, with stake and rider.[4]

The Dutch and English settlers in the seventeenth centuries had nothing but frame houses like those in the homelands. These required elaborate inventories of tools and the slow labor of splitting or sawing clapboards. Frame houses caught fire easily, bullets easily penetrated them, and in the southern colonies, where they were made of oaken clapboards, which warped, they were drafty. The style that came to house the generations on the frontier was the log cabin imported by Swedes, Finns, and Germans to the colonies on Delaware Bay. The cabin used the abundant wood, whole logs at a time, cheaply and quickly. It required no nails or other ironwork. It could be built with just one tool, the ax, If properly chinked, it was warm, tightening as the logs shrank. It

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[2] Burlingame, Roger, 1938. *March of the Iron Men.* New York and London; Randolph, Vance, 1931. *The Ozarks.* New York.

[3] Adair, James, 1775. *The History of the American Indians.* London; Kercheval, Samuel, 1850. *A History of the Valley of Virginia.* Woodstock, Va.; Rogers, Robert, 1769. *The Journals of Major Robert Rogers.* Dublin.

[4] Chinard, Gilbert, 1945. The American Philosophical Society and the Early History of Forestry in America. Proc. Am. Philos. Soc. 89:444-488; Mercer, H. C., 1929. *Ancient Carpenters' Tools.* Doylestown, Penna.

stopped bullets and fire arrows and was simply repaired. It served as the natural housing for a nation of poor backwoodsmen.[5]

While wild animals and plants supplied settlers with food, including tree sugar and the honey of European bees naturalized in hollow limbs, their basic foods were Indian corn and the Old World hog. Unlike European small grains, corn thrived in the semi-shade of girdled groves, competing with weeds and increasing many times for each kernel planted. Since the mature plant could be left standing in the fall, being harvested at will to feed human beings, livestock, and barnyard fowls, corn fitted flexibly into busy lives. And colonists learned from Indians a score of ways to use its grains, including pone and hominy.

Grass was scarce in the forest and stinging insects were abundant, and where cattle could not endure in the woods hogs found a plenty of nuts, acorns, roots, and tubers that made them grow corpulent. Besides, while a cow had only one calf a year, the razorback sow bore several litters. Razorbacks had long legs like greyhounds. They could gallop a mile and leap over rail fences, but they raised themselves without care. And once butchered, they served a dozen purposes in the household. Families felt the future was safe when they had all the pork they could eat. They were afraid when they could see the bottom of the pork barrel.[6]

Clearing the forest, splitting rails, chopping fuel, building the cabin all required the ax, and the backwoods evolved its own tool. The early colonists brought with them the European felling ax weighing about three pounds, a type virtually unchanged since Roman times. The handle was straight and round, the bit wide and flaring, the round poll so light that the axhead was unbalanced and wobbled in the stroke. In the coastal colonies blacksmiths developed axheads that were balanced. The poll grew flat, thick, heavier sometimes than the bit, and the bit lost its flare while gaining in cutting power as smiths learned to make the cutting edge by inserting steel strips and welding them. The head gained in weight up to seven pounds. The handle got longer, slimmer, took on an oval cross-section, curved so that the center of the cutting edge and the end of the handle were on the same plane. A bulb developd at the handle end to give the axman a firmer hold.[7] The American ax was the instrument that enabled the frontiersmen literally to conquer and exploit the forest, destroying it to make way for farming, or converting it into masts and boards, planks and bolts of cabinet wood.

The interaction of European and Indian culture amid the great forests of eastern America produced a unique backwoods civilization of canoeists, road blazers, hunters, scouts, railsplitters, cabin dwellers,

[5] Johnson, Amadus, 1911. *The Swedish Settlements on the Delaware.* Philadelphia and New York; Shurtleff, H. B., 1939. *The Log Cabin Myth.* Cambridge, Mass.

[6] Force, Peter, 1836-1846. *Tracts and Other Papers, Relating Principally to the Origin, Settlement, and Progress of the Colonies of North America.* Washington, D. C.; Kirkland, Joseph, 1887. *Zury, the Meanest Man in Spring County.* New York; The Elias Kiser MSS. Indiana Historical Library.

[7] Mercer, op. cit.

and lumberers. A challenge and an opportunity for men working, the process of occupying and developing the forest was a common experience that unified the nation until about 1848. Thereafter the country split into North and South, the treeless and arid plains and deserts raised brand-new problems, the Machine Age began, and Americans faced a series of new adjustments to environment, ones not yet satisfactorily made.

The Buddha Outlier of the Mansfield Sandstone Lawrence County, Indiana

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The purpose of this paper is to describe and depict the relationships of a small isolated outlier of the pebbly phase of the Mansfield sandstone formation of basal Pennsylvanian age, resting deeply in the Mississippian system, located near the cross-roads hamlet of Buddha, Lawrence County, Indiana, some 10 miles or more east of the general outcrop of the Mansfield formation. Figures 1 and 2 have been prepared to show the geologic, topographic and geographic relations of the occurrence of the Buddha outlier of this basal formation of the Pennsylvania system so unexpectedly remote from the main body of the formation and so surprisingly different in its stratigraphic surroundings. The presence of this outlier in the Buddha locality, some seven miles southeast of Bedford, was called to the attention of the writer some years ago by T. M. Bushnell of Purdue University, but it was not until recently that the outlier was investigated.

The Buddha outlier is located about one-half of a mile north of Buddha in sections 9 and 10, T. 4 N., R. 1 E. It occupies in part an easterly extending spur of dissected upland and in part the northern edge of a small section of the sinkhole upland surface, representing the Mitchell plain of southern Indiana as developed on the upland divide between the deeply intrenched valleys of East White River and Guthrie Creek. (See Figs. 1 and 2.) The small section of upland sinkhole plain is approximately 700 feet above sea level and 200 feet or slightly more above the alluviated valleys of these streams. On the upland surface are scattered patches of waterworn gravels composed of bronzed chert and small geodes, showing in some of the shallow road-cuts. These gravels represent the Lafayette upland gravels occurring so widely in the unglaciated section of southern Indiana. Normally these gravels are in place at elevations between 700 and 800 feet in altitude. Perhaps some of the gravels of the Buddha locality represent redepositions, or are residual on the limestone plain which has been lowered somewhat by subsoil solution, especially those at altitudes less than about 740 feet. A hill in section 14, about two and one-half miles southeast of Buddha, reaches an altitude of 800 feet, as shown on the Bedford Quadrangle topographic sheet, and the Lafayette gravel in place is apparently 60 feet deep. In none of the gravels of the locality were white vein-quartz pebbles observed, though it is not uncommon for them to be present in many of the Lafayette gravel areas in southern Indiana. These gravels are mentioned here because it should be made clear that they are in no way to be confused with the Buddha outlier of pebbly sandstone.

The Buddha outlier of the pebbly phase of the Mansfield formation is a narrow strip of outcrop not exceeding 100 yards in width and ex-

tending nearly east and west for a distance of about one-half of a mile. (See Fig. 1.) It forms an undulating divide or ridge rising slightly above the general level of the upland plain of the Buddha locality. The maximum thickness of the remnant does not appear to exceed 20 feet. The base was not found exposed at any place, but it appears to be about 730 feet in altitude. The maximum altitude of the ridge does not exceed 750 feet. Exposures are numerous in the form of massive boulders or surfaces on the undulating ridge and numerous free boulders or blocks of various sizes occur along the hill-side edges of the

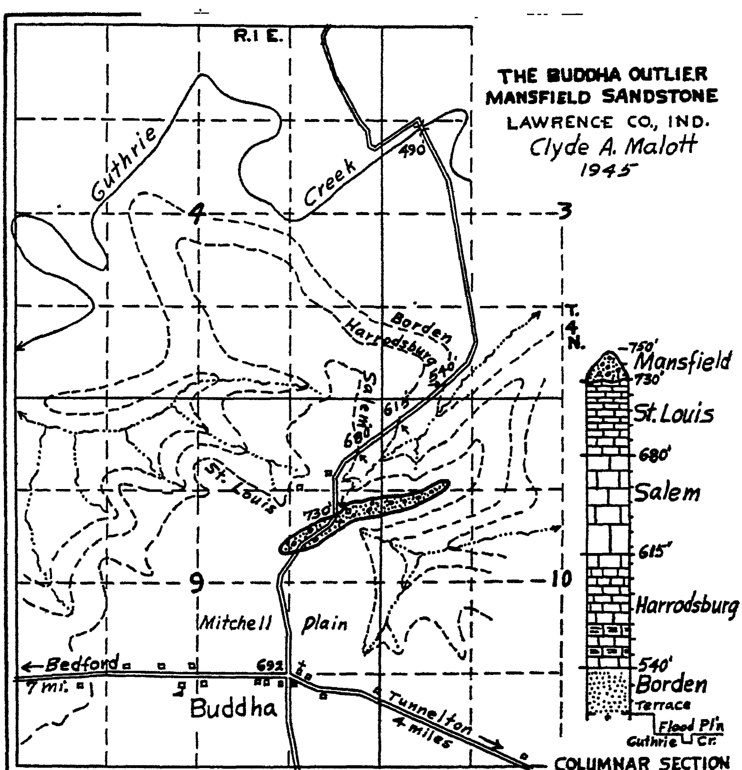

Fig. 1. Sketch of the Buddha outlier of the Mansfield pebbly sandstone showing its topographic and geologic relations.

formation, and numerous smaller pebbly boulders derived from the formation extend as float down the ravine running northeast from the deposit. No sections of the formation were available for study.

The formation appears to consist mostly of coarse quartz sand, grit and small pebbles, either loosely held together or firmly bound by iron oxide. Little local material derived from the surrounding formations appears to be incorporated in the formation, even in parts which appear to be close to the base. The sand is angular and subangular

with a minor amount of rounded grains, all of clear vitreous quartz. The grit, consisting of particles ranging from one-tenth to three-tenths inches in size, is dominantly angular and subangular, though some rounded fragments are not uncommon. The pebbles, either scattered through the sand and grit or massed in streaks in the cross-bedding of the of the formation, vary in size from small peas up to as much as one inch across. They are all quite rounded and the larger ones are elongated rather than spherical or subspherical. The grit and pebbles are composed of admixtures of opaque milky quartz, iron-stained quartz, pale-blue vitreous quartz, and clear vitreous quartz. A small quantity of dull, porous chert was observed in some of the hand specimens which were collected. The sand, grit and smoothed pebbles are rather poorly assorted, except in certain massed bands in the cross-bedding where the pebbles dominate. No true bedding was observed in any of the exposures. While the larger exposures are massive and difficult to break with a hammer, the formation does not appear to be thoroughly cemented. The cementing material is composed almost entirely of infiltrated iron oxide. The pieces of float composed almost entirely of pebbles break up readily when struck with a hammer.

The same description, perhaps with some variations, may be given to certain outcrops of the basal Mansfield sandstone formation elsewhere in Indiana, notably one and one-half miles west of Williams in the western part of Lawrence County, the Trinity Springs and Shoals localities in Martin Couty, and the Lafayette Spring locality east of Cannelton in Perry County. Since the basal Mansfield sandstone formation is the only Paleozoic formation known in Indiana with such a composition of quartz grit and quartz pebbles, it is only logical to conclude that the Buddha deposit is an isolated remnant of the Mansfield which once connected with the main body of the formation now many miles west down the dip from the severed and remote Buddha outlier.

The remoteness of the Buddha outlier from the main body of the Mansfield formation is only one of its unusual relations. It rests on the St. Louis limestone only 50 feet above the base of that formation. (See Fig. 1.) The base of the main body of the Mansfield formation down the dip in the western part of Lawrence County rests on various members of the Chester series, normally above the Cypress and Golconda formations which are respectively 395 and 440 feet higher stratigraphically than the position of the Buddha outlier on the lower part of the St. Louis limestone. This signifies that the pre-Mansfield erosion was as much as 440 feet deeper into the Mississippian system in the Buddha locality than it was in the area of the main body of the Mansfield in the western part of Lawrence County. The following formations with their normal thicknesses in the Huron locality were apparently eroded away before the deposition of the Buddha representative of the basal Mansfield formation:

Golconda	45 feet.
Cypress	35 feet.
Beech Creek	15 feet.

Elwren	35 feet.
Reelsville	5 feet.
Sample	30 feet.
Beaver Bend	15 feet.
Mooretown	20 feet.
Paoli	20 feet.
Aux Vases	5 feet.
Ste. Genevieve	115 feet.
St. Louis	110 feet (of the upper part).

No other locality in Indiana is known to have such a great stratigraphic range in the overlap of the base of the Mansfield sandstone.

The basal Mansfield where composed of or containing quartz pebbles, such as the Buddha representative, is largely confined to fillings in the more deeply eroded valley-like depressions in the underlying formations upon which the Mansfield unconformable rests. In the area of the eastern margin of the formation through Indiana the basal parts of the Mansfield are composed of its more normal sandstone phase or of a shale where it occupies its normal stratigraphic position. The pebbly phase

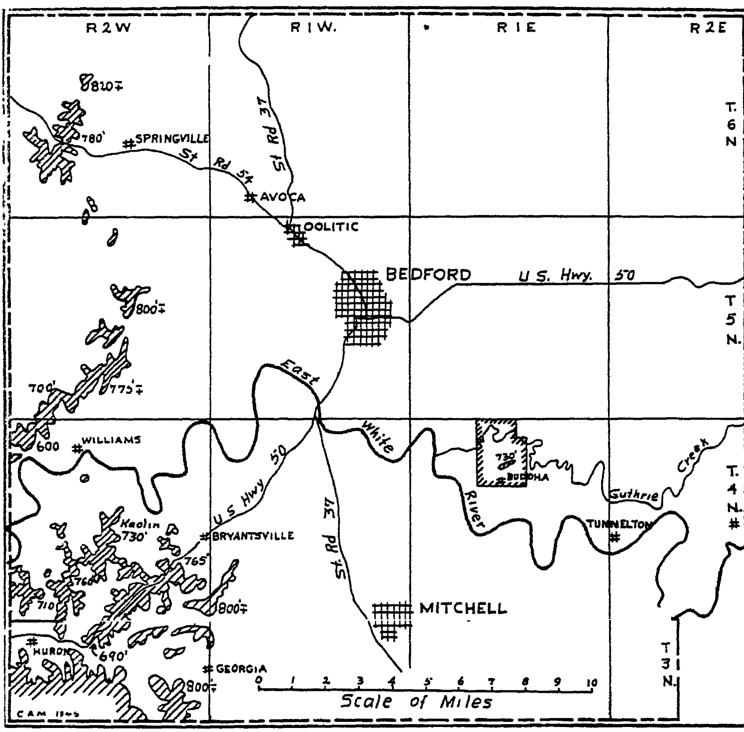

Fig. 2. Sketch of Lawrence County, Indiana, showing the position of the Buddha outlier in its remote relation to the ridge-crest outcrop of the basal Mansfield in the western part of the County. Figures express the variable altitudes of the Mansfield base.

is characteristic only of its base where it bites deeply below the normal stratigraphic position of the locality where such phases of the formation occur. Accordingly, the Buddha outlier is very likely a remnant of a Mansfield filling in a deep pre-Mansfield valley.

Some of the variabilities in the altitudes of the base of the Mansfield formation in the western part of Lawrence County are shown in Fig 2. The base of the eastern edge of the much eroded and dissected fringe of the main body of the Mansfield is at an altitude generally of about 800 feet, which is 70 feet higher than the altitude of the base of the Buddha outlier 10 miles away up the dip to the east. But the main body of the Mansfield in the southwestern part of Lawrence County has considerable variation in the altitudes of its base, especially west of the eastern fringe where data on the base are more readily available. The normal stratigraphic position of the base in Lawrence County is on the Cypress and Golconda formations, but in the Bryantsville-Huron area the base digs deeply below its normal stratigraphic position, in places coming below the Beech Creek limestone, and has a local relief in excess of 100 feet. On U. S. Highway, 50, one and one-half miles southwest of Bryantsville, the base rests on the Elwren shale at an altitude of 765 feet. At the old kaolin mines three miles west of Byrantsville, the Mansfield base of coarse, cross-bedded, massive sandstone is at the horizon of the Beech Creek limestone about 700 feet in altitude. Two miles southwest of the kaolin mines, the base of the Mansfield is at its normal position on the Golconda formation at an altitude of 760 feet. These altitudes not only represent the westerly dip of all the formations of some 30 feet per mile, but they show a variation in stratigraphic position as well.

It is in the locality west of Williams, however, that the Mansfield bites most deeply into the Chester formations. Here, a loose, pebbly phase of the Mansfield rests on or near the Beaver Bend limestone at an altitude of 595 feet, stratigraphically 120 and 165 feet respectively below the tops of the Cypress and Golconda formations. The loose, pebbly Mansfield has been dug or quarried for road material just north of the overhead bridge across the railway on State Road 450. Some redeposited iron-stained clay derived from the pre-Mansfield clay residue of the Beaver Bend limestone occurs in the base of the Mansfield in the quarry pits, along with some fragments of redeposited white kaolin. The pebbly phase of the Mansfield here occupies a pre-Mansfield valley as much as 150 feet below the nearby pre-Mansfield uplands. This old pre-Mansfield valley with its pebbly fill of the Mansfield formation extends west and southwest some four miles to the well developed, pebble-filled pre-Pennsylvanian valley in the Indian and Trinity Springs locality, mapped and described some years ago by the writer. It is not unreasonable to speculate on the possibility that the Buddha outlier is a remnant of the pebbly filling deposited in this same pre-Pennsylvanian valley.

It is quite certain that the Buddha outlier is an isolated remnant of the pebbly phase of the Mansfield deposited in a pre-Pennsylvanian valley trough which was cut deeply below the normal position of the

Mansfield base. It appears too deep, however, to be wholly accounted for by a pre-Pennsylvanian valley alone. It indicates severe truncation eastward of the underlying formations previous to the deposition of the Mansfield sandstone, and suggests that some aspects of the presence of a pre-Mansfield Chester escarpment, perhaps not greatly unlike the one which today lies just west of Mitchell between the main body of the Mansfield and the Buddha outlier.

Calcitic Pisolites Forming in Travertine Cascade Deposits

ROBERT R. SHROCK, Massachusetts Institute of Technology

On a recent geological trip to the Southern Peninsula of Haiti, the writer came upon an active multi-terraced travertine deposit in which pisolites are abundant and appear to be forming at the present time. This brief article proposes to describe the conditions under which the travertine deposit is being built and to record data on the size, structure, and composition of the pisolites.

Location and Geology of Deposit

Sault du Baril, the local name given to the waterfall and cascades where the travertine is being deposited, is located a few kilometers inland from the coastal village of Petite Rivière some 20 kilometers west of Miragoane (Fig. 1). Here, at the head of a valley over a hundred meters

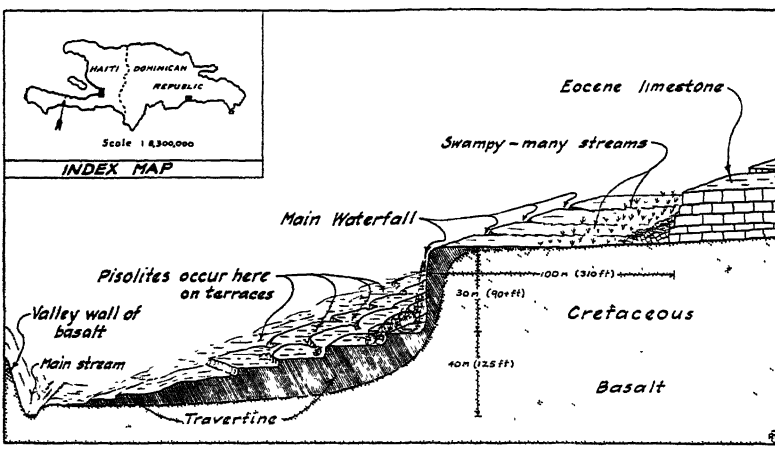

Fig. 1. Diagram of Sault du Baril showing relations of travertine cascade deposit to waterfall and underlying bedrock. The view is looking northeast. Pisolites occur in abundance on the terraced deposits at the base of the great waterfall.

deep, water heavily charged with calcium carbonate flows out along the contact between Eocene limestone and underlying Cretaceous basalt and, after a short course across a flat swampy terrace, plunges over the crest of a spectacular travertine deposit, in a dozen individual streams, and falls in a turbulent mist to the terraced deposits over thirty meters (100 ft.) below (Fig. 1). The fallen waters then gather themselves together into individual streams which flow swiftly and sinu-

ously downward, across an extensive ever-growing deposit of travertine, ultimately joining along the narrow valley bottom and thence flowing on to the sea near Petite Rivière.

Through the centuries, for the falls seems to have been in existence for a long time, the spring-born waters have been extending the crest of the waterfall until there is now a great wedge of travertine built against the upper part of the basalt valley wall (Fig. 1). At the foot of the almost vertical waterfall there is a broad, multi-terraced deposit of travertine which reaches down to the very bottom of the valley. This deposit seems also to have the shape of a wedge because it becomes thinner toward the valley bottom and at one point near the bottom a low knoll of the underlying basalt shows through.

The cool spring-born waters, saturated with calcium carbonate, almost immediately start precipitating their load as they become warmer and more turbulent. One sees many evidences of this early precipitation of calcium carbonate in the ashen-gray coatings on vegetation adjacent to the streams and in the heavy coatings left as shells around roots and tree trunks and around pieces of limestone lying on the surface. One sees further evidence as he walks or rides along the path following the crest of the falls. Here many small streams of swiftly flowing water follow narrow channels in travertine bounded by smooth "botryoidal" sides.

As one descends afoot the steep, crumbly face of the waterfall far to the left of the present flow, he sees everywhere great masses of sponge-like travertine containing leaves, twigs, branches, and even whole trunks of trees, all encased in a hard shell of rocky calcium carbonate. This situation is the one which often gives rise to the idea that the waters are "petrifying." On the gentler slopes and terraced segments around the base of the precipitous slope, one sees many tubular shells of concentrically stratified calcium carbonate lying about, doubtless the remnants of tree coatings from which the wood has disappeared.

Having attained the base of the precipitous part of the travertine deposits, one now has to thread a tortuous path through low bushes, ashen-gray with their limy coating, across many fragile steps and terraces of travertine which are literally growing out of the swiftly flowing streams which course beneath the bushes. After following a guide for perhaps a hundred meters, one comes out onto a broad, gently convex, somewhat terraced surface developed on friable travertine.

Here one has an excellent opportunity to examine this material called *travertine* which Webster's International Dictionary defines as "a white concretionary calcium carbonate, soft and chalklike to hard and semi-crystalline, deposited from the water of springs or streams holding lime in solution." The definition fits the Haitian material perfectly. Here, at Sault du Baril, lime-laden waters have deposited such a mass of gray to light brown, friable to firmly cemented travertine—some as coatings and films on rocks and trees; some as loose or solid rock. Precipitation of the calcium carbonate takes place through loss of carbon dioxide which may be due to rise in temperature, aeration of the water during its turbulent fall and flow, or to the action of certain plants.

The result is this spectacular deposit which makes one think of a gigantic stairway leading to a stage with the curtain a 30-meter high, 100-meter long precipitous rock wall vertically banded with streams of shimmering white water losing themselves in mist at the base. The sight is well worth the 3½-hour horseback ride from the point where the river empties into the sea.

Occurrence and Nature of Pisolites

The pisolites are abundant in the friable gray travertine constituting the numerous terrace segments and inter-terrace slopes directly below the part of the waterfall where water was coming over at the time of our visit (May 11, 1945). Little if any water was flowing across the area where the loose pisolites were picked out of the friable travertine. The area seemed to be one of past rather than present deposition. It was assumed, from observations made at the time of the visit, that the concretions form at the base of the falls, where the water is broken into spray, and in the swiftly coursing waters which gather from the mist and find their way downward across existing travertine deposits. Bits of rock, leaves, twigs, etc., act as nuclei to start precipitation, and deposition once started continues as long as conditions are favorable. Many of the concretions have not been transported far, if at all, from the place where they grew judging from their shape and surface features; some, however, because of their spherical shape and polished surface probably were transported from the site of formation, though they could also

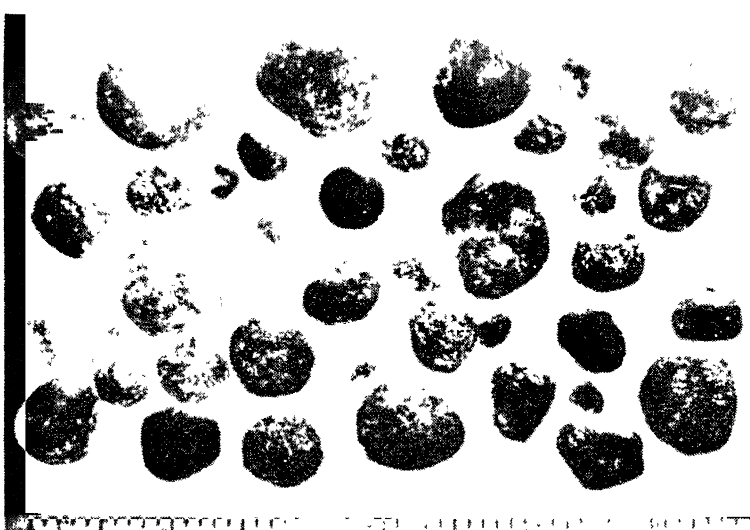

Fig. 2. Typical pisolites from the travertine cascade deposits at Sault du Baril, Haiti. The scale is in inches (1″=25 mm.).

develop those features by being rolled about in an enclosed basin of turbulent water.

The pisolites range in diameter from less than 2 mm. to more than 30 mm. Smaller irregular concretionary particles were seen; these, however, did not appear to be true concretions of oolite size but rather tiny aggregations of crystals. Some of the smaller pisolites are almost perfect spheres, many are spheroidal or ellipsoidal, and some of the larger are ovoid or irregular in shape because of rounded protuberances (Fig. 2). Generally the surface is hard and more or less smooth but occasional pisolites have a granular surface due to the porous, friable nature of the material.

Internally the pisolites are composed of concentric shells of denser, and stronger material separated by a zone of poorly cemented grains

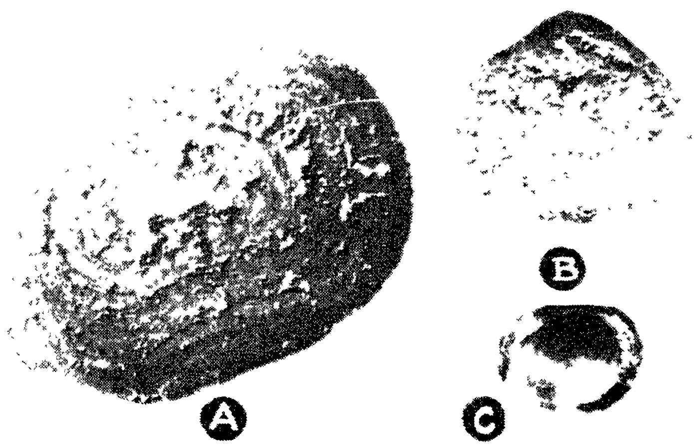

Fig. 3. Cross-sections of typical pisolites. A. Large, concentrically banded pisolite with hollow center. B. Medium-sized pisolite with a nuclear fragment of basalt. C. Small specimen with part of outer shell broken away. (All figures are magnified x 2.8).

which show no structure (Fig. 3). Each type of material was X-rayed and both were found to be calcite.* The difference in structure seems to be a matter of cementation and recrystallization. No radial structure was observed in any of the concretions.

Most of the pisolites that were broken or sectioned showed no visible nucleus but some did have a prominent cavity at the center suggesting

* I am indebted to Dr. H. W. Fairbairn, Massachusetts Institute of Technology, for making the X-ray analysis.

the possibility that there may once have been some sort of nuclear material. In one specimen (Fig. 3) a tiny bit of basalt constitutes the nucleus.

Under the conditions which prevail at the cascades, it is probable that any tiny bit of foreign matter—leaf, twig, rock fragment, or loose grain of travertine—would initiate precipitation and act as a nucleus around which a concretion could grow. Deposition once started would continue as long as conditions were favorable. All field evidence supports the view that the pisolites were formed as free, discrete bodies which later came to rest, in some instances after transportation, in the midst of granular travertine.

It seems altogether probable that with increasing age and burial the structure of the pisolite may change from alternating zones or shells of dense and porous material to a fairly uniform dense texture.

When the pisolites are dissolved in normal hydrochloric acid, there is violent evolution of carbon dioxide. After all chemical action has ceased the solution contains some gelatinous material. A small portion is organic and disappears on ignition. The remainder is iron oxide and silica.

Surficial Breccias Produced from Chemical Weathering of Eocene Limestone in Haiti, West Indies

ROBERT R. SHROCK, Massachusetts Institute of Technology

A common surface feature in limestone areas where chemical weathering is unusually active is a veneer of angular fragments of the rock that is being attacked. Under favorable conditions, on slopes and in channels and crevices where waters saturated with soluble salts circulate, the fragmental material may be cemented sufficiently to form a rigid, sheetlike mass. In this manner, certain ancient formations composed of angular fragments and commonly referred to as breccias may well have been formed. The purpose of this brief article is to describe a case in which a surface veneer of angular fragments—a potential surficial breccia—is being produced by chemical weathering of limestone.

During the spring of 1945, while conducting geological exploration in the Republic of Haiti, West Indies, the writer had an unusual opportunity to observe how limestones respond to tropical weathering at an elevation of 1500 to 2000 meters.

Rains on the high plateau around Mt. La Selle, where chemical weathering is so active, are seasonal, with two periods of heavy precipitation alternating with two periods of lighter precipitation or none at all. Initial drainage is largely downward and laterally through the limestones until the flow reaches a major valley trenching the plateau. Here, along the steep slopes, the water issues as springs. The features discussd below are related to the geologic work performed by the waters while they are flowing through the surficial debris and the limestone beneath.

The limestone involved in the weathering is a remarkably pure, white, rather dense and fine-grained rock of Eocene age which typically shows quite thick beds with only a few prominent joints. Close examination of the rock, however, reveals myriads of closely spaced but tight incipient joints, both straight and curved, which are characteristically enlarged during the weathering. There are several distinct stages in the weathering process and these will now be discussed.

In the initial stage the limestone surface is attacked most noticeably along the many tight joints and takes on the appearance of a slightly etched mosaic (Fig. 1A). In addition to the etching along joints, intervening blocks of the mosaic often develop a fretted or corrugated surface.

The second stage is reached when solution along joints reaches deeply enough into the rock that individual joint-controlled blocks stand almost completely free from the rock mass as a whole. Early in this stage it is not uncommon for numerous eyelets, pipes, and round cavities to develop along the joints and late in the stage the rock exhibits a cavernous nature on a grand scale (Fig. 1A).

The third stage is marked by partial or complete disintegration of the rock into surficial rubble composed of angular fragments that

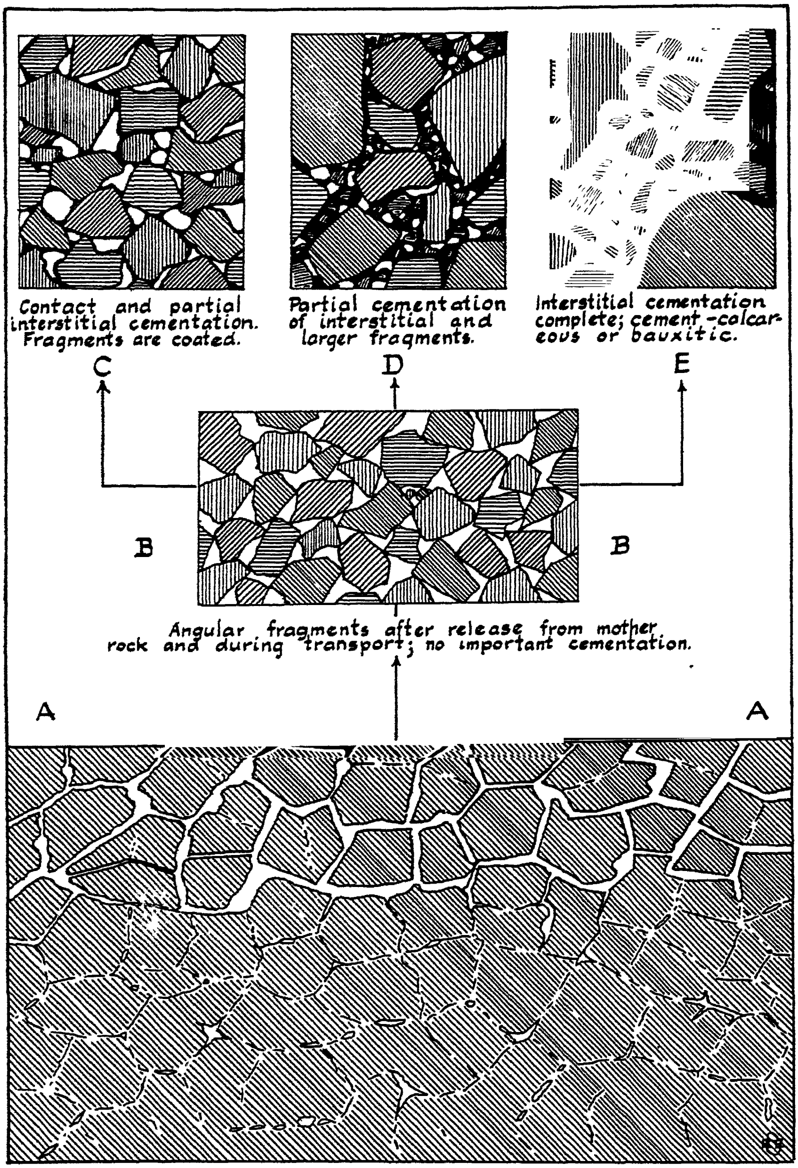

Fig. 1. Diagram showing how massive, incipiently jointed limestone is gradually disintegrated into polyhedral fragments with planar and curved surfaces. These angular fragments, after release from the mother rock, are transported down slopes mainly by sliding. When they come to temporary or permanent rest, circulating ground waters precipitate calcareous material in the interstices and cement the fragments into a rigid mass. Small fragments and residual soil may filter downward into the mass and fill a large portion of the interstitial space. In these cases also circulating ground waters may bring in calcareous matter and partially or completely cement the entire mass (D and E). These sketches are based on specimens and observations made in the field.

usually can be measured in inches. If the slopes are gentle, the rubble is almost certain to be cemented into a continuous layer before it moves far. If, on the other hand, the slope of the surface closely approaches or exceeds the angle of repose for the materials involved, the fragments may slide downward for considerable distances before coming to rest in a stable position. Then they too are likely to be cemented (Fig. 1A-B).

In the third stage the accumulation of angular fragments may develop either of two characteristic textures. In the simpler type, fragments of essentially uniform size are packed together loosely with maximum interstitial space. Such texture favors free and rapid circulation of ground water and since these waters are heavily charged with calcium carbonate, the fragments are quickly cemented together where they touch and are coated where their surfaces are not in contact. Continued deposition in the interstitial spaces ultimately produces a rock composed of angular fragments firmly cemented together by calcareous material which fills part or all of the interstices (Fig. 1C).

The more complex type of texture consists of a skeleton of large fragments, like those of the simpler type, with interstices filled by smaller angular fragments of several sizes which have sifted down through the larger interstitial openings. During subsequent cementation some of the smallest interstices are left unfilled whereas the larger are completely filled. The coating so commonly observed in the simpler type of texture is uncommon in the more complex type.

The fourth and last stage in the weathering process is that of extended or complete cementation. The resulting surficial crust or layer lacks any semblance of stratification and if incompletely cemented has the appearance of coarse concrete aggregate to which only a limited amount of fine aggregate and cement have been added for binding. The completely cemented rock breaks across fragment and cement alike and a surface has the appearance of a mosaic (Fig. 1E).

This general type of surficial breccia has not been recognized in any of the better known classifications of breccias[1], but the writer does not propose a term for it here pending further investigations.

During the weathering cycle just discussed, red residual earth, often with composition approaching that of bauxite, is left behind as the soluble limestone is dissolved. It may filter downward along with small limestone fragments into the enlarged joints of the country rock or into interstices of the surficial rubble and itself in conjunction with calcareous material act as a cement to bind the fragments into a rigid mass. Rock of this kind is not uncommon at various localities in Haiti and the writer has observed the same thing in Jamaica. In this type of breccia the white limestone fragments appear in some instances to float in the red bauxitic matrix. Woodring[2] has suggested *solution breccia*

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[1] Bonney, T. G., On the relation of certain breccias to the physical geography of their age, Quart. J. Geol. Soc. London, 58:185-206 (1902); Norton, W. H., A classification of breccias, J. Geol., 25:160-194 (1917); Reynolds, S. H. Breccias, Geol. Mag., 65:97-107 (1928); Twenhofel, W. H., *Treatise on Sedimentation*, 2nd edition, Williams and Wilkins, 1932, pp. 236-239.

[2] Woodring, W. P., et al., *Geology of the Republic of Haiti*, Dept. Public Works, Port-au-Prince, 1924, p. 109, 132, 134.

for the type here illustrated in figure 1E. In suggesting the designation he states (p. 109), "Cavities dissolved in the limestone are commonly refilled with soil and sediment that is recemented with calcareous material, producing a mass of rock that may aptly be termed solution breccia . . ."

Fragmental deposits of the type here described are probably not common in the geologic column because they are made where active solution is going on above the base level of erosion and are likely to be destroyed as the general terrane is reduced. Under abnormal geological conditions, however, as for example faulting, such a deposit might be buried and preserved. It would undoubtedly be designated some sort of limestone breccia but its origin might not be obvious. The characteristics of these unusual types of surficial breccia have, therefore, been considered worth recording so that they might be tested as a possible explanation of certain sedimentary breccias now preserved as rock in the geologic column.

Karst Features in Maya Region of Yucatan Peninsula, Mexico

ROBERT R. SHROCK, Massachusetts Institute of Technology

It is the purpose of this brief article to discuss a few interesting karst features of the recently elevated, low limestone plateau which constitutes the northern part of the Yucatan Peninsula (Fig. 1). The features are located at and near the ancient Maya cities of Chichen Itzá and Uxmal. The observations on which this article are based were made during the spring of 1944 while doing geological reconnaissance in northern Yucatan. The writer was accompanied by Dr. Walter L. Whitehead, Massachusetts Institute of Technology, with whom he was fortunate to discuss the subject matter presented here.

Nature of Surface.—The peninsula of Yucatan has special interest for the student of geomorphology because of its youthful stage in the subterranean drainage cycle. It is a recently elevated plain, developed on fairly soft, flat-lying, chalky limestones of late Tertiary age, which rises gently southward from the Gulf of Mexico, where it stands only a few tens of feet above sea level, to over 500 feet above sea level in the jungle country of northern Campeche and northwestern Quintana Roo (Fig. 1). The region to be discussed in this article is probably not over 150 to 200 feet above sea level except for the prominent northwest-southeast trending ridge a short distance north of Uxmal (Fig. 1). There is a very interesting karst plain on the southerly backslope of this ridge,

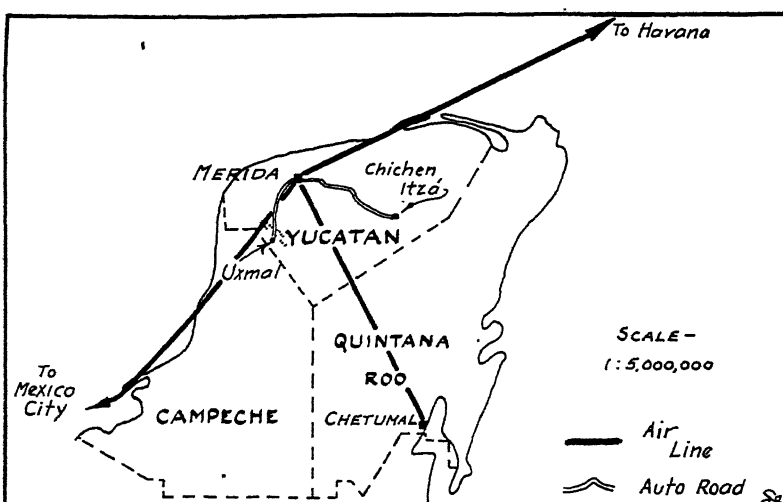

Fig. 1. Outline map of Yucatan Peninsula showing cities and towns mentioned in text.

which appears to be a fault block tipped to the south and scarped on the north side. Red residual soil has washed from this plain through gullies in the crest of the ridge and has been spread out on the north side of the scarp in the form of red alluvial fans which are quite apparent from the air. There is also an abundance of small caves and sinks in this same ridge. These have been very interestingly described by Mercer (1896), who explored a number of them in search for remains of aboriginal culture.

Between Mérida and Chichen Itzá to the east and Uxmal to the south, there is a gentle undulating surface of isolated and interconnected shallow basins of solution separated by low rounded knolls and ridges of limestone. Morris (1931, p. 2) aptly described the surface when he wrote as follows about an automobile trip from Mérida to Chichen Itzá "We moved as upon the back of a great measuring worm, now up, now down across the alternate sequence of swales and hummocks." Many of the depressions have a thin accumulation of red residual soil derived by solution from the surrounding limestone and concentrated in the lower part of the basin through surface wash. When viewed from the air, the red soil areas have a pattern like that of a jig-saw puzzle (Fig. 2). The actual area covered by soil never exceeds 50 per cent

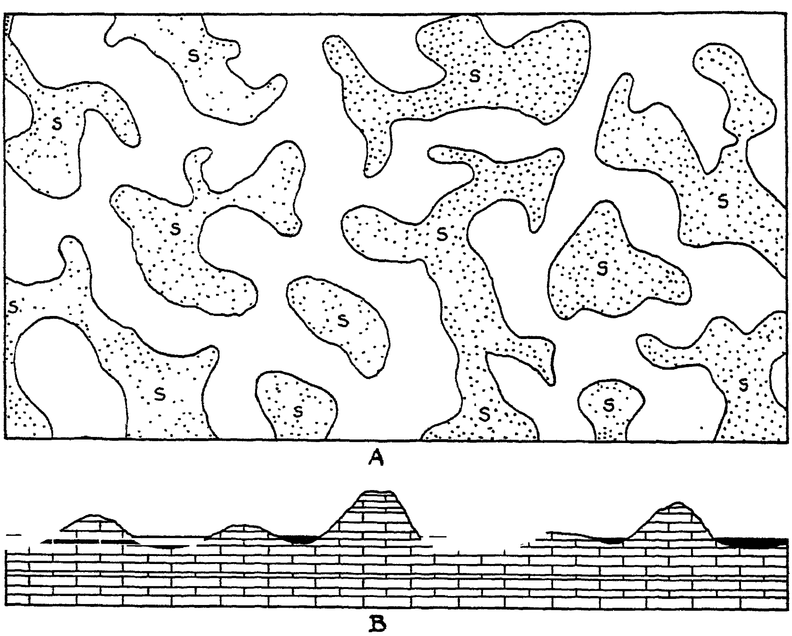

Fig. 2. Karst topography in Mérida region. A. Ground plan of soil-covered basins (s) and intervening ridges as seen from air and ground; the area is about one-half mile wide and one mile long. The area of red soil varies from 10%-50% of the total surface and the soil itself is rarely over five feet thick. B. Cross-section along bottom edge of A showing basins and ridges. The limestone ridges range in height from 1 to 50 feet and usually are covered by rubble.

of the total surface area and probably averages nearer 25 to 30 per cent. No soil deposits greater than five feet in thickness were seen.

There are no continuous channels or surface drainage. Water which falls washes down the bare limestone slopes, carrying to the bottoms of the intervening depressions whatever residual soil has accumulated in the crevices of the weathered rock, and then sinks through the porous residual soil mantle into the limestone beneath. The crevices and holes into which the downward moving water flows are not commonly conspicuous, but at a few places well-like sinks called *cenotes* have developed as a result of subterranean drainage and subsequent collapse of the cavern roof. It is an interesting fact that these cenotes do not lie in the center of shallow depressions, as they should if they represented outlets for sinkhole drainage, but rather on flat limestone surfaces.

The most notorious of the cenotes is the celebrated "Sacred Cenote" at the ancient Maya city of Chichen Itzá, but there are many other equally interesting ones in the general Mérida region. The writer counted a dozen circular ponds scattered over the karst plateau southeast of Mérida en route by plane to Chetumal and these are presumed to be cenotes similar to those seen on the ground. Brief references to some of the better known of these cenotes are made by Berlin (1898), Schenck (1906), and Willard (1926), who refer to them incidentally in discussing various aspects of the Maya civilization which flourished in the Yucatan region many centuries ago. Mercer, in his work on the hill caves of Yucatan referred to on a previous page, shows by diagrammatic cross-sections the relations of a number of cenotes to the underground caverns which he explored.

Vegetation.—A dense, almost impenetrable jungle of vines, bushes and low trees covers the Yucatan plateau except where the inhabitants have cleared the land for cultivation. Corn is the usual crop raised on the less rocky red soil areas and henequen (sisal), the chief crop of commerce which is cultivated for its hemplike fibre, flourishes on the rocky slopes.

In southern Yucatan and northwestern Quintana Roo the dense jungle, in which is the heart of the chicle country, consists of hilly areas of large, coarse-looking green trees separated by irregular flat tracts of finer textured, lighter colored vegetation. It was later learned that the zapote trees, which are the source of the gum chicle, prefer the rocky hills whereas swamp and marsh vegetation cover the lower flats where the soil is deeper. Karst topography borders the chicle country on the northwest and may also be present beneath the heavy jungle growth but this could not be determined from the air. It was learned, however, that the soil is thicker as one travels southeast from the Uxmal region.

Description of Cenotes (Natural Wells)—The cenotes, which appear to be scattered over the Yucatan plateau without a definite pattern, are vertical solution tubes which have been greatly enlarged particularly in the equatorial plane by slump and collapse. The early shape of a typical cenote is that of an upright brandy glass without the stem;

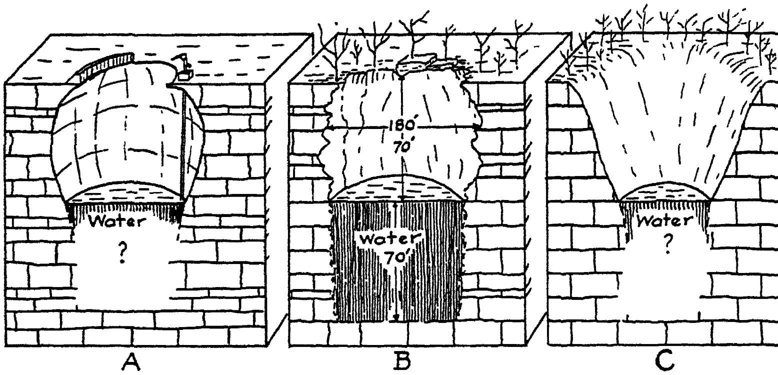

Fig. 3. Cenotes. A. A jug-shaped cenote at Libre Union west of Chichen Itzá. It is about 60 feet deep and 50-60 feet across. Water is pumped from the pool in the bottom to supply the village. The depth of the water could not be ascertained. B. Sacred Cenote at Chichen Itzá. The well has an elliptical opening and the brink overhangs to some extent. The outwardly curved wall has prominent encircling ribs and grooves produced by differential weathering of the flat-lying chalky limestone strata. C. Bowl-shaped cenote observed along the road to Uxmal south of Mérida. The depth appeared to be about 70 feet and the pool in the bottom fairly small. The depth of water was not determined. All diagrams are exaggerated vertically about twice.

i.e., smaller at the surface opening than half way down, and rounded bowl-like in the bottom (Fig. 3A). If the entire rim collapses, the shape is roughly cylindrical (Fig. 3B). Outward migration of the rim produces a bowl-shaped basin with the pool typically occupying most of the bottom (Fig. 3C). Several cenotes of the last type, with circular pools in the bottom, were observed along the road from Mérida to Uxmal.

The local inhabitants, descendants of the ancient Maya, have long depended on the cenote pools as a source of water, hence the name "natural well," and archeologists (Morley 1925, p. 65-66; 1936, p. 622) have concluded that the great Maya cities were located near cenotes for this reason. At the little village of Libre Union, on the road from Mérida to Chichen Itzá, there is a typical cenote about 50-60 feet across and about 60 feet deep. Water from the pool is pumped to the brink and is used locally (Fig. 3A).

Early in 1944 the writer saw a cenote similar to those of Yucatan on the flat karst plain east of Ciudad Trujillo in the Dominican Republic. This feature was described on the spot in the writer's field notes as follows:

"At 37 kilometers east of Ciudad Trujillo, on the north side of the highway, is a remarkable jug-shaped sinkhole known locally as the 'Indian Well' where, it is reported, the ancient inhabitants of this part of the island used to come for water. The cavity is about 25 meters deep, 15 meters in diameter near the bottom and perhaps 10 meters across at the surface opening. Stalactites hang from the walls which flare out

toward the bottom. At the time of our visit (Feb. 4, 1944) a pool of water covered perhaps half of the bottom of the sink.

"Indian Well and the numerous shallow sinkholes observable from the highway between Ciudad Trujillo and San Pedro de Macoris indicate extensive subterranean drainage on the elevated limestone bench along the coast."

The most famous of the Yucatan cenotes is "Sacred Cenote" or the "Well of Sacrifice" in the ancient Maya city of Chichen Itzá. According to archeologists (Morley 1925, p. 80-81; 1936, p. 622 and pls. XVI and XVII), young maidens were hurled into the well in times of great national necessity as living sacrifical victims. At the same time that the girls were thrown in, the Itzá people, who lined the brink during the ceremony, cast their prized possession after her, presumably with the hope of appeasing the gods. These possessions included numerous kinds of jade ornaments, gold and copper bells and rings, carved bones, wooden weapons and pottery.

Many of these articles were recovered about 40 years ago by dredging and are now on display at the Peabody Museum of American Archeology and Ethnology at Harvard University. A detailed description of the dredging operations and of the objects recovered from the bottom muds, which lay beneath over 60 feet of water, will be found in T. A. Willard's interestingly written "The City of the Sacred Well" (The Century Co., New York, 1926).

The Sacred Cenote is about 180 feet across at the top, somewhat larger at about half-depth, and generally cylindrical to the water's edge (Fig. 3B). The water surface of the pool is 65 to 70 feet below the rim of the cenote and the water is reported to be 70 feet deep and never to vary in level. Water level in the second cenote at Chichen Itzá is also about 70 feet below the surface but its depth does not seem to have been determined.

Geomorphological Significance of the Cenotes—The water table at Chichen Itzá stands at about 70 feet below the limestone plateau, but the elevation of the bottom of the cenote (about 140 feet below the surface) is not known. Concerning the depth of the cenotes, Morley (1936, p. 591) states, "The cenotes and modern wells vary in depth directly with the increasing elevation of the land as one withdraws from salt water, from only a few feet at the coast to about 100 feet in the interior. The level of the subterranean water table, however, always remains the same." It has been reported that no salt water is encountered in the cenotes except immediately adjacent to the coast where sea water mingles with fresh water in some of the sinks.

The elevation of the bottoms of the Yucatan cenotes has special significance for the following reason. Accepting the conclusion that the Yucatan Peninsula has recently been elevated, it follows that if the bottoms are now below sea level or above by less than the amount of uplift, subterranean drainage was active at elevations lower than the present water table. This does not mean, necessarily, that the under-

ground features resulting from solution were formed below the water table of the time. It is quite possible that these features were made during the part of the Pleistocene when sea level and water table both were lowered. Precise data on surface and subsurface elevations will have to be obtained, however, before any definite statement can be made about the level at which subterranean drainage developed.

Archeological Interest—The karst plain of Yucatan has special archeological interest because it is one of the regions where the Maya civilization attained a high state of development. Its sparse soil supported a community large enough to raise the great pyramids and temples that are today in partial ruin and the underlying limestone furnished the building materials for the structures. Water used in construction, as well as for domestic purposes, must have come from the natural wells because there seems to have been no other natural source of supply and no evidence remains to conclude that the Maya ever employed catchments and cisterns for water storage.

The archeology of the Yucatan Peninsula has been investigated in considerable detail and has been discussed in many publications but little about the geology has found its way into print. Since the life of the ancient inhabitants was so closely related to the karst features of the terrane, study of the geology offers a very worth-while field of investigation and should be encouraged.

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Sedimentation and Wind Action Around Volcan Parícutin, Mexico

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During a recent visit[1] to the well-known active volcano, El Parícutin,[2] southwest of Mexico City in the state of Michoacan, the writer was impressed by the important role the wind was playing in the redistribution and ultimate deposition of volcanic ash blown out from the active crater. This article proposes to discuss briefly certain aspects of the wind action and some of its geological implications.

Nature of eruption. During a typical eruption there is a great column of ash-laden gas above the 1,500-foot high cone (Fig. 1). The column, composed of successive outbursts, frequently reaches upward many thousands of feet before losing its identity through disruption by high-altitude winds. These wind currents, blowing across the column in various directions, spread the ash in an extensive triangular cloud. Ultimately the ash falls to earth from this cloud, covering the entire surface with a gray or gray and black mantle (Figs. 2 and 3).

Nature of Surrounding Terrane. Upon leaving Uruapan to visit the volcano, one travels for miles across a gently rolling countryside covered by a mantle of gray and gray-black ash strongly reminiscent of a heavy snowfall in northern latitudes (Fig. 2). The trees and shrubs are heavily weighted down with ash, sharp hills and the rough surfaces of geologically recent lava flows appear much smoother because of the ash mantle, and stream courses are so choked with ash that the water frequently has been forced out of its old channel and made to follow a new one. These recently cut ravines, some over ten feet deep, reveal excellent sections of beautifully graded and stratified ash, mostly black in the coarser basal portion of layers and lighter gray in the finer grained upper part. The old roads have long since been lost under the ash and the provisional automobile trails wander over the ash flats with regard only for attaining some objective in the distance—a situation somewhat like that on the sand flats of southeastern United States.

Wind Action Around and Near Volcano. During the afternoon on the day the visit was made, the surface winds were not strong but there was enough turbulence that one had to protect his eyes and nostrils from the impalpable dust which seemed to fill the air at times even on the windward side of the volcano. On the leeward side there was a

[1] The visit was made on May 12, 1944. Dr. Walter L. Whitehead, Massachusetts Institute of Technology, accompanied the writer and deserves a vote of thanks for several suggestions.

[2] El Parícutin, Estado de Michoacan, Universidad Nacional Autonoma de Mexico, Instituto de Geologia, Estudios vulcanologicos, Mexico, 1945.

heavy ashfall, judging from the height and size of the columnar cloud above the crater (Fig. 1).

About 9:30 P.M., perhaps an hour and a half or two hours after the sun had set and the surface of the ash had cooled, there arose a strong wind blowing toward the volcano. This wind, apparently produced by the strong updraft of heated gases in the column over the crater[3] (Fig. 3), finally became so strong that the air was filled with

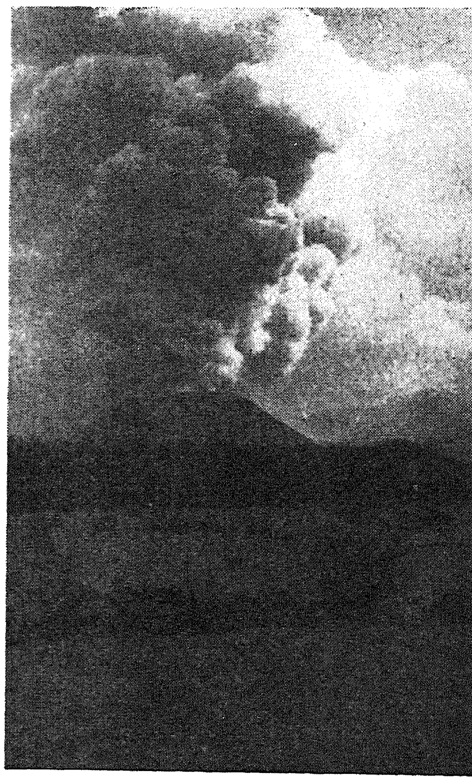

Fig. 1. View of El Parícutin, May 12, 1944, showing typical ash-laden column above the crater.

ash swept up from the surface. The sight of the volcano, made spectacular by the fiery trajectories of incandescent bombs, was blotted from view and the visitors had to retrace their steps to the nearby village. These strong nocturnal winds undoubtedly have been partly responsible for sweeping the ash off much of the surface of the recent

[3] It is probable that there also was some convection over the internally incandescent lava tongues which have flowed out from the volcano, but this is considered unimportant when compared to the strong updraft above the crater.

Fig. 2. View of heavily ash-covered terrane along the trail to El Parícutin from San Juan de los Conchillas, May 12, 1944.

lava flows and depositing it in the lower parts of the terrane. Diurnal surface winds have also probably played an important part in this same process.

Farther away from the volcano, where the eruptive activity does not interfere with normal meteorological conditions, local and regional winds are constantly disturbing and redistributing the newly fallen ash. In this process the ash is blown off the higher and more exposed slopes and hilltops and ultimately deposited in lower, more protected

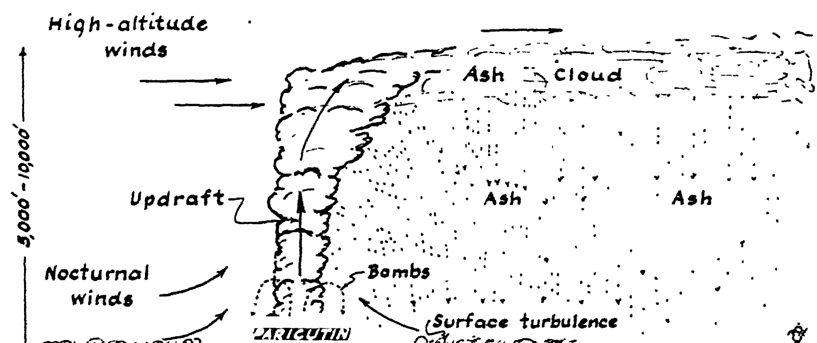

Fig. 3. Diagram showing high-altitude winds blowing ash-laden gases away from volcano and surface nocturnal winds blowing toward the volcano, the latter as a result of the strong chimney-like updraft over the crater.

areas (Fig. 4). Ripple-marked surfaces seen on some of the ash flats attest local transport. Small whirlwinds, a few tens of feet across and a hundred or so feet high, are a common sight on the white ash flats in the early afternoon. Fourteen of these were observed at once in an ash-filled basin between low, bare-rock hills. Their general effect must be to level exposed ash deposits.

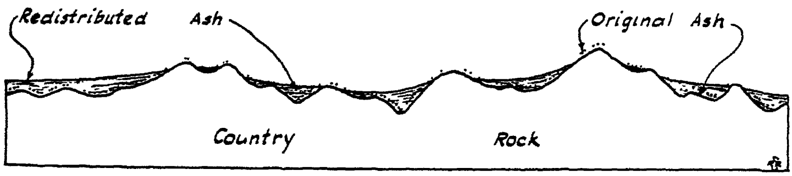

Fig. 4. Diagram to show how original ash mantle is eroded and redistributed by wind action, resulting in denudation on higher more exposed places and deposition over lower, more protected areas, with general smoothing of terrane.

Summary and Conclusions. It is here suggested that wind action around an ash-erupting volcano is an important force in redistributing the ash and forming extensive ash flats surrounding volcanic peaks. Farther afield prolonged wind action is believed to affect widespread redistribution of ash with a general tendency to level the terrane by transporting material from higher to lower places. Torrential rains are also undoubtedly important in locally transporting ash, but the water soon loses its competency by sinking into the highly porous material.

It is suggested that wind action, like that which may be observed today in the vicinity of El Parícutin and farther away, may well have played an important role in forming the extensive ash plains of the central plateau of Mexico. Furthermore, it seems altogether likely that wind was an important redistributor of ash during past epochs of volcanic activity, especially before there were any land plants to protect the surface materials.

Sand

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In retracing some of the "footprints in the sands of time," my mind goes back to a conversation some two years ago with my aunt, then eighty-four years young. She referred to "maple sand," a common "pest" to the maple-syrup makers in Vermont. The implication was that this "sand" had come up as sand from the soil through the circulatory system of the maple tree and then settled out in the boiling down of the sap. The resulting argument, as in so many cases, was based merely on lack of definition of terms. There *is* such a thing as maple sand, but it has *not* come up as sand from the soil. It's a fine, white, crystalline, rather impure calcium malate which, because of its relative insolubility (as compared with sugar) precipitates before the sugar in the syrup and sugar making. The solubility of calcium malate at 0°C. is 0.812 gm. per 100 cc. of water as compared with a solubility of sucrose, under the same conditions, of 179 gms. This relative difficulty of solution of the calcium malate as compared with sugar will explain the feeling of the maple-sugar maker that it is as insoluble as sand and the resultant naming of the material, "sand." Examination of two specimens of maple sand indicates a material much finer than what is usually called sand.

Table I. Grain Analyses of Two Specimens of Maple Sand[1] According to Modified Wentworth Classification. (Table II.)

	Coarse Sand ½ mm. plus	Fine Sand ½ mm.-1/16 mm.	Silt 1/16 mm.-1/256 mm.	Clay less than 1/256 mm.
a.	5.7%	8.5%	22.8%	62%
b.	3.5%	3.5%	45.5%	48%

Biologically the term sand is also applied to various kinds of material in the human body, such as brain, kidney, bladder, and prostate "sands." "Brain sand" is composed of irregular, agglutinated, yellowish or reddish grains found either in the pineal body or areas of toxoplasmic disease in the cortex.

Although pineal bodies do not consistently show brain sand, there is no positive evidence that its presence indicates a diseased condi-

[1] Specimen a, courtesy of the Vermont State Department of Agriculture; and, b, courtesy of Bradley St. John, Fairhaven, Vermont.

tion. In fact, when present, this pineal sand may perform a valuable function, if an x-ray photograph of the brain is necessary to determine the presence of a brain tumor. Such a brain tumor may not show up plainly on x-ray photographs, but, if present, it will frequently displace the pineal body from its normal median position. The pineal sand will photograph, thus showing the displaced position of the pineal body, and therefore indicating the side on which the brain tumor has developed. Kaufman (20, p. 1819) describes the pineal sand as mulberry-like reddish bodies composed of calcium carbonate with a layered albuminous material of unknown origin. Although it is not indicative of any specific disease, the amount of pineal sand frequently increases from about eight years.

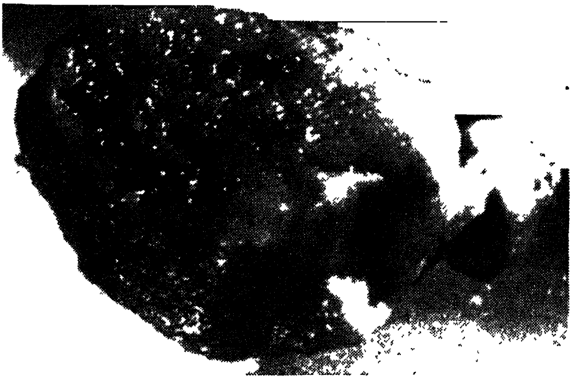

Fig. 1. Photo Showing Human Pineal Body with a Section Removed from the Left Side, Exposing Pineal Sand. Courtesy of J. W. Papez, M.D. Photo, K. V. Palmer.

Brain sand in the cortex is positive evidence of various types of diseased condition in the brain—*tuberous sclerosis, toxoplasmosis,* possibly as *sclerotic* patches on the cerebral blood vessels.

The balancing mechanism of vertebrate animals contains *otoliths* (*otoconia* in the human body) frequently of the size of sand grains suspended in the inner ear. These bodies, either single or multiple granules (usually calcium carbonate) in a gelatinous mesh, are suspended in the endolymph in contact with the free ends of hairs projecting from the maculae, sensory areas of the utricle and saccule of the membranous labyrinth. Because of their size these granules frequently fall in the range of sand (Table II) and in the dog-fish shark *(Squalus acanthias* L.*)* actual grains of sand are used in this balancing mechanism. These grains are drawn down into the saccule through the endolymphatic duct. An examination of the grains from the balancing mechanism of one dog-fish,[2] which may or may not be typical, gives the following distribution of grain-sizes: between 28 and 297 microns, with the finer

[2] Obtained through the interest of Professor W. E. Martin.

Fig. 2. Copy of "Lateral Surface of the Brain Showing the Distribution of Patches of Tuberous Sclerosis." (18, p. 234)

sizes the more abundant. In the Wentworth classification of clastic grains (Table II), 11/20 grains would be silt; 6/20, very fine sand; 3/20 fine sand.

Kidney and bladder sand may be found in the kidneys, pelvis, urinary bladder, gall bladder, urethra and prepuce. The bodies range in size from very fine sand up to a diameter of several inches. The most common components according to Kaufmann (20, p. 1410) are: (a) uric acid or urates. The urate stones are the most common, moderately hard, with a soft granular or nodular surface, yellowish brown or reddish brown color, laminated structure; (b) calcium oxalate. These stones are small, warty, colorless or stained with hematin. They may be composed of alternate layers of calcium oxalate and urates; (c) calcium or ammonium magnesium phosphate. These are formed in alkaline urine.

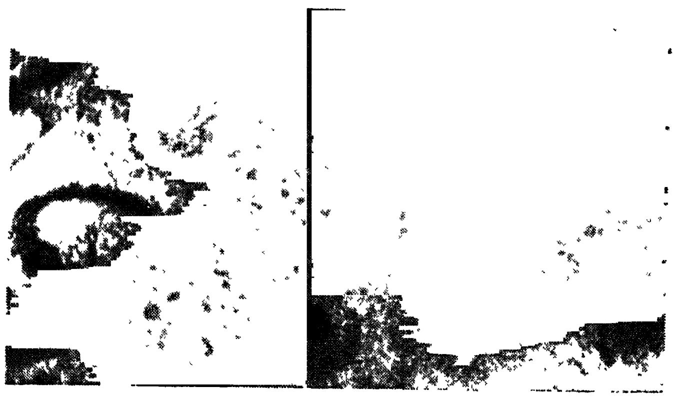

Fig. 3. Copy of Section of the Cerebellum Showing Small Cavities Encrusted with Calcium Carbonate. (Nissl's Stain, Low Power.) (18, p. 241)

Prostate sand. Cross-sections of prostates of older men contain almost constant yellow, brown or black granules from the size of grains of snuff to that of a pea or larger. On examination of the prostate gland they may be felt through the rectum. (20, p. 1520)

Geologically, sand may be defined as fragmental rock material intermediate in size of grain between gravel and silt. The British classification as proposed by Boswell (1918) (27a, p. 108) differs from the American geologic practice as proposed by Wentworth. (50, p. 507)

Table II. Wentworth Classification of Clastic Particles on the Basis of Grain Size.

Boulder	.256 mm. plus
Cobble	.256-64 mm.
Pebble	.64-4 mm.
Granule	.4-2 mm.
Very coarse sand grain	2-1 mm.
Coarse sand grain	1-½ mm.
Medium sand grain	½-¼ mm.
Fine sand grain	¼-⅛ mm.
Very fine sand grain	⅛-1/16 mm.
Silt Particle	1/16-1/256 mm.
Clay particle	less than 1/256 mm.

In this classification, then, all sedimentary grains 1/16-2 mm. are in the sand range. In the opinion of the writer the Wentworth classification is a backward step as compared with the British in that it is based so largely on common fractions instead of decimals, the fundamental basis of the metric system.

In addition to the British and American geological classifications, The International Society of Soil Scientists have their own classification which with slight modification is shown in Table III.

Table III. Classification of Soil Grain Sizes as Adopted by the Int. Soc. of Soil Scientists. (40, p. 12)

Coarse sand grain	2.0 -0.2 mm.
Fine sand grain	0.2 -0.02 mm.
Silt	0.02-0.002 mm.
Clay	less than 0.002 mm.

Relation of Grain Size to Origin

A recent paper by Keller (22, p. 215) reports that a study of 700 samples from Pacific coast dunes and beaches, 370 samples from inland dunes as far east as Dunes Park, Indiana, and 272 samples of the St. Peter sandstone in Missouri, the Tensleep and Wyopo sandstones in Wyoming and the Navajo sandstone in Utah gave the following results: Beach sands are approximately four times as coarse as corresponding dune sands. The inland dunes seem to be more variable in coarseness

than the dunes near the beaches. Comparison of the St. Peter, which has been frequently considered of eolian origin, with the beach and dune sands indicates definitely that the St. Peter had a beach origin.

Composition of Sands

Although commonly sand is thought of as being composed of quartz, it is considered technically as being of no single composition, but as being of a definite range of grain size as determined by the specific method of classification used. In general, it has been assumed that the number of minerals in a sand or sandstone decreases with distance from the source. Shaler reported (43) that "an unusually pure beach sand is found at West Palm Beach, on the Atlantic Coast of Florida (probably Palm Beach, E. R. S.), nearly everything but quartz being eliminated." Russell (41, p. 1347), however, in his study of samples of Mississippi River bottom sediments from Cairo to the Gulf concludes that the selective destruction of the "less resistant" minerals (either chemically or physically) has been generally overestimated. The hypothesis, that the presence of "less resistant" minerals in a sand indicates a nearby source, has no factual basis. "The absence of the 'less resistant' minerals in sediments should be attributed largely to solution and alteration either in the source rocks or after deposition rather than to destruction during transport."

The following is a list of sixty-eight minerals, with comments, found in various sands. There is no hard and fast boundary in the discussions of the minerals in this list between sand and gravel.

Actinolite is uncommon in desert sands studied by White. (52, p. 745) According to Condit (8, p. 154) the amphiboles are more common in Ohio glacial sands than in older sands and sandstones.

Albite. Where a sand is the result of deposition after rapid disintegration of granular, acid, igneous rocks, it frequently contains abundant, only slightly weathered, acid feldspars such as orthoclase, micròcline, and albite. Such a sand or resulting sandstone is called arkose. Essential conditions, it is generally believed, are: (a) granitic terrane, (b) rapid disintegration and (c) quick deposition. As noted above, Russell discounts entirely the significance of any ordinary concept of quick deposition. (41, p. 1347) Twenhofel states (47, p. 229) that rapid disintegration is favored by aridity, high altitude, or high latitude. White, on the other hand, (52, p. 747) concludes: "It may be of interest to note that none of the (desert) sands studied was appreciably arkosic, a fact that would seem at complete odds with any conjectural notion of the mineralogy of sands of desert origin." Barton (2, p. 439), in his very complete study of arkose, states that it may be formed under less rigorous conditions—usually in deposits of smaller size, in which the feldspar is less fresh, showing the beginning of the decomposition process. The common argillaceous odor of arkose may be due to such predepositional decomposition or to decomposition after deposition as arkose. (E.R.S.) Albite (var. moonstone) has been found in the bed of Williams Creek, Indianapolis, Ind. (49)

Allanite is reported by Russell to be fairly common in all samples from Cairo to the Gulf, although always less than 1% of the heavy minerals. He considers that the infrequency of mention of allanite in detrital sediments is due to lack of recognition rather than to its absence. (41, p. 1328)

Anatase. In one sample of desert sand.

Andalusite. Of 33 desert sands studied by White, (52, p. 745) four showed andalusite.

Apatite. About one-third of the desert sands studied by White (52, p. 745) showed apatite in greater or less abundance.

Augite. The pyroxenes and other ferro-magnesian silicates are uncommon in sands or sandstones unless they are the result of quick deposition of rapidly disintegrated, granular, basic igneous rocks. When cemented, such a rock is called graywacke. (47, p. 175) Because of the ease of decomposition of most of the basic minerals, graywacke is not as common as arkose.

Barite. White reports barite as rare in three of the 33 desert sands studied. (52, p. 745)

Biotite. Uncommon in desert sands. (52) Bleached and battered flakes are found in the Mansfield sandstone of Indiana. (12, p. 131)

Brookite is reported by Gault (12, pp. 131, 132, 133) as a persistent heavy mineral in the Mansfield sandstone. He concluded that it had developed *in situ* because of the perfection of the crystals and because they are sometimes found projecting from fragile specimens of leucoxene.

Calcite is probably the commonest mineral cementing sand grains into sandstone. It is also common (below the zone of weathering, E. R. S.) as comminuted fragments in glacial sand. (8) Many cases of marine sands of nearly pure $CaCO_3$ are reported. Such fragmental, calcareous sands are deposited in the "sand zone" especially off shores of a land of low relief. After deposition, the sand may be picked up by the wind and redeposited in calcareous dunes. There are such dunes on Bermuda composed of coral, mollusk and foram shells or fragments. In addition to the marine calcareous sands deposited off low-lying land areas, fragmental calcareous sands are deposited off shores composed predominantly of limestones. Cases of this type are found on the beaches of Anticosti Island and Gotland where over 90% of the sand grains are of limestone. Calcareous sands, of whatever origin, are characterized by the common features of other sands such as ripple marks and cross-bedding. (47, p. 250) It is probably true that some of the cross-bedding in the St. Genevieve limestone of Indiana, such as may be seen in the old quarries on the penal farm at Putnamville, is of sand-dune origin, although some as evidenced by the coarseness is of beach origin. (E. R. S.) White, (52, p. 744) as a result of his study of desert sand, states: "Calcite is, to be sure, not uncommon in sediments of subaqueous deposition, but in those of desert origin it is ubiquitous."

Cassiterite is the chief mineral of tin placer deposits.

Ceylonite was found in one sample of desert sand. (52, p. 745)

Chlorastrolite (49) found by Dr. Kelso while panning for gold in Brown County, Indiana, is believed to give very positive evidence of the direction of movement of the Illinois glacier—Isle Royale in Lake Superior to Brown County, Ind. Native copper and native silver found in the "gold counties" of Indiana give similar evidence, Keweenaw Peninsula origin. (49)

Chlorite, glauconite, greenalite, serpentine, and epidote are chiefly responsible for the green color of sandstone. Chlorite was found by White in three desert sands. It is a sporadic mineral in the Mansfield sandstone. (12, p. 132)

Chromite. One of the heavy minerals reported in sands and sandstones.

Clinozoisite was reported by White as rare in three desert sands.

Collophane is not commonly reported in clastic sediments. Martens (27) has pointed out the frequency of its occurrence. Russell (41, p. 1331) suggested that, since nearly all samples of lower Mississippi sediments showed collophane, its infrequency of mention may be due to its solubility in acids with which sediments are frequently treated before study.

Corundum. Wade (49) reports, not only chatoyant crystals of common corundum, but also ruby and sapphire of fine quality from the Indiana "gold counties."

Diallage is reported by Russell as being fairly common, but less than 1% of the heavy minerals, in Mississippi River sediments.

Diamond. Occasionally, when panning for gold, there are picked up here and there in the "gold counties," not only in Indiana, but also Ohio, Michigan, Illinois and Wisconsin, diamonds of excellent water up to more than five carats in size. There are records of at least eleven diamonds from Indiana alone. Hobbs has reported a 17ct. and a 23ct. diamond from Wisconsin. (49) These were brought down by the Pleistocene glacier from some as yet undiscovered diamond lodes in Canada. These are but a sample of the tremendous diamond production from placer deposits—streams, the ocean, winds —in South Africa, Belgian Congo, Gold Coast, Sierra Leone, British Guiana, Brazil, Borneo, and India. (17, p. 323)

> "In 1835 the great British scientist, Sir David Brewster, stated that, 'Were the diamond not as a gem the head of the mineral kingdom, it would have attained the same distinction from its great utility in the arts.' World War II has certainly proved the truth of this statement. There is no important war weapon that does not employ the diamond in its manufacture." (28, p. 1567)

Diopside. In five of the 33 desert sands studied by White, diopside was reported.

Dolomite is a fairly common cement in sandstones. It is reported by Russell as a common constituent of Mississippi River sediments.

Enstatite is reported by White from five desert sands.

Epidote. Frequent but not always abundant in desert sands. (52) In the Mississippi River sediments up to 10% of the heavy minerals. (41, p. 1328)

Fluorite. Rare in two desert sands studied by White. (52)

Garnet is the coloring mineral in red sands which are common on the Great Lakes and the oceans. Condit (8) reports its common occurrence in glacial sands of Ohio and in the Triassic sandstones of Connecticut and New Jersey. He also suggests that the rarity of garnet in certain pre-Triassic sandstones, such as those of Ohio, is evidence of non-metamorphic sources. Gault (12, p. 132) reports garnets of several colors in the Mansfield sandstone. White found garnet "frequent, but not omnipresent" in the 33 desert sands studied. (52, p. 745) Russell reports three varieties of garnet, one at times up to 17% of the heavy minerals, in the Mississippi River sediments studied.

Glauconite (green sand) occurs in rocks of nearly all ages. Because of its appreciable per cent of potassium, glauconite is frequently used as a locally obtained fertilizer. Its origin has aroused the interest of some of the best mineralogists, but as yet there is no unanimity of opinion. Two schools of thought may be briefly summarized: (a) the glauconite is formed in the presence of organic matter from ferrous sulphide, clay, a potassium compound and water; (b) the glauconite is the result of the progressive decomposition of biotite under marine conditions. (48, p. 402) Glauconite is reported by Russell as never common in the Mississippi River sediments, although it is not an uncommon mineral in the rocks of the upper Mississippi valley (E.R.S.) and in the Tertiary sediments through which the Mississippi flows. (41, p. 1327)

Glaucophane is reported from one desert sand by White.

Gold. Native gold is the ore mineral of placer gold deposits, be they marine sands, present stream deposits or deposits from the geologic past. Placer gold was the gold of the '49 gold rush and the Klondike. It is still the mecca of the lone prospector. For a number of years, however, somewhat less than ⅓ of the U. S. production has been placer gold. (28) A good prospector can see an unbelievably small speck of gold or "color", as he calls it, in his pan. Lindgren (25, p. 253) states that a particle of gold worth 1/2000 cent at the old price ($20 per oz.) can be spotted. Even so, more specimens of "fool's gold" than of real gold are sent in to state geologists for identification. However, once in a while, even in Indiana, real gold is found. Especially in Morgan and Brown Counties, the "gold counties",

a good many thousands of dollars worth of gold have been recovered by farmers in "off seasons", by men out of work or by the butcher, the baker, the candle-stick maker, with gold-panning as a hobby. This gold, like the chlorastrolite, the copper, the diamonds and the silver, was brought down from the north by the great Pleistocene ice sheets. A state inspector of concrete aggregate saw his chance when sand and gravel were being washed from Big Walnut Creek in Putnam County, Indiana, for the new U. S. No. 40 four-lane highway. Twice a day, he would put a strip of Brussels carpet, 27 inches by 48 inches, in the washing flume. When the washer was stopped at noon and in the afternoon, he would take out the strip of carpet, dry it by the fire, and beat it out over a piece of brown paper. Together with much quartz and magnetite sand, at the end of five weeks, he had over $250 worth of gold. In my desk, also, are three grains of gold washed out by David Taylor, a Putnamville H. S. boy, from Mosquito Creek just south of Putnamville, Ind.

Gypsum. The widely known white sand dunes of Otero County, New Mexico, appearing from a distance like white-caps on an inland sea, are largely composed of nearly pure granular gypsum. It had been eroded from "ribs" of Permian gypsum rising at intervals above the saline flats. (16) Gypsum is also a common constituent of the salts deposited in desert playas.

Halite. Thoulet (45) has reported minute amounts of halite in desert sands outside of playas, but in playas it is so abundant as to have been the basis of the Grabau-Walther theory of the origin of great salt deposits.

Hematite. Condit (8, p. 159) reports that hematite is found as inclusions in quartz and as a cement in red sandstone. White (52, p. 745) noted hematite as a common constituent of desert sand. Surprisingly, Russell (41, p. 1328) reports hematite as more common than limonite in the sediments of the lower Mississippi.

Hornblende. Condit (8, p. 158) reports the hornblende in Ohio sandstone as being much weathered. Sandstones with considerable hornblende would be considered as graywacke. Gault reports hornblende as a sporadic mineral in the Mansfield sandstone of Indiana. (12, p. 133) Russell (41, pp. 1319, 21, 23, 25) found hornblende up to 15% of the heavy minerals. According to White, half of the 33 desert sands studied showed hornblende and it was abundant in two samples. (52, p. 745)

Hypersthene was found in glacial sands by Condit; common in a few desert sands by White; fairly common (up to 3% of the heavy minerals) by Russell.

Ilmenite, whose local abundance in beach sands of Florida has given those sands economic importance, is one of the heavy minerals. To its black color, not that of magnetite, is due the name "black sands" of the heavy-mineral sands of Florida. These heavy minerals have been carried by streams and shore currents from the states between Virginia and Georgia down to Florida. Since the heavier minerals tend to be dropped first, unless they are markedly finer grained than the average, the sparsity of such minerals as ilmenite in the beach sands from Virginia to Georgia poses, in the opinion of the writer, a very real geomorphological problem. Is it not very probable that in the Pleistocene the drainage from the source states was directly to Florida instead of into the Atlantic farther north? Further evidence of the reasonableness of such a suggestion is the distribution of the heavy minerals on both sides of the Florida peninsula. In the Mansfield sandstone of Indiana, Gault reports ilmenite as making up 5-20% of the heavy minerals. (12, p. 133) In the Florida deposits 43%. (34) It is frequently abundant in desert sands. (52, p. 745) Mississippi River sediments contain high, although variable, percents (6-50% of the heavy minerals) of ilmenite. (41, p. 1328)

Iolite was reported from the dune sand of Holland. (36)

Iridosmine. This natural alloy of iridium and osmium is derived chiefly from placer deposits.

Kaolinite. Various clay minerals are reported disseminated and in "clay balls" in sands and sandstones.

Kyanite. About one-third of the desert sands studied by White contained kyanite. (52, p. 745) Russell reported kyanite as rare up to 1% of the heavy minerals in the lower Mississippi sediments.

Leucoxene is a heavy mineral, decomposition product of ilmenite and found associated with that mineral in the Mansfield sandstone of Indiana, 40-70% of the heavy minerals; (12) not common in desert sands; (52) 1-7% of the heavy minerals in the lower Mississippi sediments; (41) and astonishingly not listed from Florida by Phelps. (34)

Limonite is regarded by Condit as equally omnipresent with quartz, although usually not over 3-4%. It is the cement in brown sandstones, such as the famous stone of the "brown-stone-fronts", so widely built along our eastern seaboard at the end of the last century.

Magnetite is the common mineral of black sands (not Florida) and can be separated out with a magnet. It is generally not of economic importance because of its low tenor and also its high percent of titanium due to associated ilmenite. In gold panning, the gold is usually found with a magnetite residue in the bottom of the pan. One dune sand from California contained 15% magnetite. (38, p. 385) For economic reasons, the Japanese are said to have concentrated and utilized marine sands as iron ore. White reports that magnetite was not common in desert sands studied. It is but a sporadic mineral in the Mansfield sandstone of Indiana. (12) Russell reports that the percent of magnetite in the heavy minerals in the Mississippi sediments varies between 0.9 and 42%. (41, p. 1318 et seq.)

Marcasite is not commonly reported in sands and may be mistaken for pyrite.

Microcline. Discussions of albite and orthoclase apply to microcline, although it is reported by H. R. Wanless as the most resistant of the feldspars.

Monazite sand is the chief commercial source of the "rare earths"—thorium, cerium, lanthanum, praseodymium and neodymium. With the decline in the use of thorium for Welsbach mantles, other uses for thorium and the other rare earths have been sought. Resulting uses include glass, ceramics, alloys, printing and dyeing, and moth- and rot-proofing of textiles. (28, p. 767)

Muscovite is a common mineral, although not in large amounts, in sands and sandstones. Both rust-stained muscovite and bleached biotite have been mistaken for gold. In the Mansfield sandstone of Indiana, muscovite forms 1-10% of the heavy minerals. (12, p. 132) Muscovite is one of the uncommon minerals in the lower Mississippi sediments.

Nephelite.

Olivine was found in one desert sand by White and rare to fairly common in the lower Mississippi sediments by Russell.

Orthoclase is reported in the sands of Ohio as usually more altered than albite. (8, p. 158) Russell reports (41, p. 1326) orthoclase up to 3% of the total minerals on the 100-mesh sieve. He shows surprise at the amount of fresh feldspar in these lower Mississippi sediments.

Platinum. In peace times, only a small part of the world production of platinum comes from placer deposits. Such sources, however, can be so rapidly increased in time of war that they provide much greater amounts during the war years. The absence of platinum from the Canadian "shield" is indicated by its absence from the glacial deposits in the "gold counties" of Indiana, etc.

Pyrite. White reports pyrite in one of 33 desert sands studied. Gault reports it as sporadic in the Mansfield sandstone of Indiana. Russell found pyrite from rare to 45% of the heavy minerals in the Mississippi river sediments. (41, p. 1318 et seq.)

Quartz. Although, as pointed out, to be sand, a sand does not have to be even over half quartz, it is the chief constituent of practically all sands. It is so frequently over 95% as to suggest the correctness of the general impression that sand is quartz.

Rutile was found in about one-third of the desert sands studied by White. (52, p. 745) It is not common in the lower Mississippi sediments. Gault reports that rutile is 1-10% of the heavy minerals in the Mansfield sandstone. (12, p. 133) Phelps reports it as the third commonest (10-26%) of the heavy minerals in the Florida deposits. (34, p. 168)

Serpentine.

Sillimanite. Of 33 desert sands studied by White, five showed sillimanite, one in abundance. (52) Sillimanite was reported as rare to less than 1% of the heavy minerals in the samples studied from the lower Mississippi. (41, p. 1330)

Silver. Wade reports that one of his students found a specimen of native silver in the gravels of Fall Creek, Indianapolis. On analysis, the resemblance to Keweenaw-Peninsula silver was striking—another evidence of direction of ice movement. (49) Silver is frequently found in placer deposits, but in much smaller amounts than gold.

Spinel.

Spodumene was reported in two desert sand samples studied by White. (52)

Staurolite is found in sands derived from metamorphic regions. It is reported by White to be frequent, but not omnipresent, in desert sands; (52, p. 745) and by Phelps sporadic in Florida sands. (34)

Sylvite occurs in minute quantities in some desert sands and in larger amounts in playa deposits.

Titanite is uncommon in desert sands (52) and up to 3% in lower Mississippi sediments. (41, p. 1318 et seq.)

Topaz was reported by White in two desert sands, none in the lower Mississippi sediments studied by Russell.

Tourmaline is reported by Phelps as a minor constituent of Florida heavy sands; by Gault in the Mansfield sandstones, as 5-20% of the heavy minerals; by White as widely distributed in amounts less than 1% in desert sands; by Russell as widely distributed in amounts less than 2% in the lower Mississippi sediments.

Vesuvianite is reported in two desert sands studied by White.

Xenotime.

Zircon was reported in desert sands by White; as second commonest (13-26%) heavy mineral in the Florida deposits by Phelps; (34) 20-50% of the heavy minerals in the Mansfield sandstone by Gault; (12, p. 133) by Russell (41, p. 1330) up to 9% of the heavy minerals in the lower Mississippi sediments; by Wade (49) as colorless to violet crystals in Indiana glacial sands.

Zoisite was reported by White as rather common in small quantities in desert sands; (52) and by Russell in small amounts in all samples of Mississippi sediments. (41)

The preceding list is certainly not complete, yet it is believed to contain most of the minerals which have been reported from sands.

Shape of Sand Grains

The most complete study of sand grains ever carried out was by Ries and Conant of Cornell Univ. (38) Certain of their conclusions follow:

Sands produced by weathering of igneous or metamorphic rocks would probably be angular and rough; glacial, stream and beach sands

may also be angular because of brevity of the grinding processes. Volcanic sands would usually show volcanic glass or pumice and have an angular or splintery form. Transportation may cause rounding of the grains either by corrasion or, as pointed out by Galloway, if in water, by solution. (10) In water, the contact grinding is counteracted to some extent by the film of water surrounding the grains, which acts as a cushion—the cushioning effect being greater, the smaller the grains. Galloway notes that rounding due to solution will be more important, the finer the grain. (10)

In wind-blown sands the rounding due to corrasion may affect smaller grains than in the case of water-borne sands. Although Galloway (11) states that, if over 50 per cent of the grains are well rounded, the sand is wind-blown, Ries and Conant report many wind-deposited sands with comparatively few well rounded grains. Rounding of hard grains is evidently a very slow process for few marine or river sands show a large percentage of rounded grains. Of 58 river sands, only 22 showed rounded grains and abundant in only a few. Of 59 marine sands, only 19 showed rounded grains. Even in these cases some of the rounded grains may show characteristics inherited from a previous wind-blown environment. (38) The sand from West (sic) Palm Beach mentioned above was described by Shaler (43) as having mostly subangular grains, though the material has been transported for many miles along shore from the Piedmont region to the north.

E. M. Kindle has pointed out that sand grains are rounded by passage through the bodies of marine animals such as sea urchins. (23, p. 431)

The question arises, "How round is a sand grain?" Trowbridge and Mortimore (46, p. 405) used the terms: "well rounded," "fairly well rounded," "sub-angular," "angular," but the use of such descriptive terms will vary with the individual. Wentworth suggested methods of study and classification which could be used on pebbles and larger rocks. (51) E. P. Cox (9, p. 180) suggests a definition of roundness, the circularity of a two-dimensioned figure, which may be measured in a decimal fraction in the following manner:

$$\frac{\text{Area}}{(\text{perimeter})^2} = \text{constant},$$

which is $\frac{1}{4\pi}$ for a circle. Therefore, the above equation multiplied by 4π gives

$$\frac{\text{Area} \times 4\pi}{(\text{perimeter})^2} = \text{K}.$$

K is a constant that is dependent upon the shape of the figure, being 1 for a circle and less than 1 for any other shape, but it is the same for all figures of the same shape regardless of size. K for a figure of any given size represents the percentage ratio that the area of the figure holds to the area of a circle with the same perimeter. The constant for a square is 0.785, for a given right isosceles triangle, 0.54—the percentage roundness of those two figures.

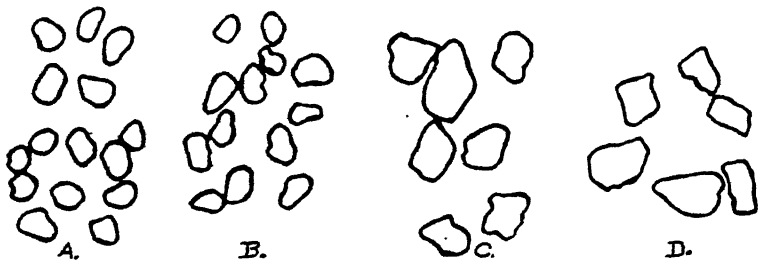

Fig. 4. Tracings of photographs of sand grains diagnosed by Trowbridge and Mortimore as (A) "rounded," (B) "fairly well rounded," (C) "subangular," and (D) "angular." A mathematical study of these tracings according to the Cox method (9, p. 181) indicates an average sphericity of A—0.902; B—0.85; C—0.88; D—0.76. This would indicate that grains called "subangular" by Trowbridge and Mortimore are more rounded than those called "fairly well rounded."

Several methods for measuring these values for a set of grains are suggested by Cox. Where thin sections or photographs have been made, project the image on a screen. Loose grains may be sprinkled on a lantern slide previously covered with a thin layer of mucilage and the image projected on a screen. The area may be measured by a planimeter and the perimeter by a map-cyclometer. The suggestion is made to substitute the map-cyclometer for the pointer of the planimeter, the results set on slide rule and the ratio read off directly as the figure denoting "roundness."

It is suggested that the above equation overlooks the factor of roughness which, unless "smoothed out," would markedly increase the denominator. Of course, where a particle has been transported far by either wind or water, a surface originally rough due to differential chemical or physical weathering would be somewhat smoothed in the rounding process.

Sherzer (44, p. 634) quotes a table from Mackie (26) indicating, possibly too "roughly," the "roundability" (*psephicity*) of the common sedimentary minerals in water and in air.

Table IV. Relative *Psephicity* of Sedimentary Minerals in Water and Air (Sherzer after Mackie)

Quartz	.23	.38	Orthoclase	.29	.40
Labradorite	.29	.45	Hornblende	.39	.57
Biotite	.70	1.05	Muscovite	.86	1.30
Magnetite	.70	.86	Garnet	.39	.53
Tourmaline	.30	.43	Zircon	.45	.59
Rutile	.51	.68			

In addition to roundness, sand grains which have been transported and eroded by wind frequently assume the appearance of ground glass. Where grains with this type of surface are found in water-laid sediments, as in the Pleistocene marls of Florida, it is concluded that they show evidence of an earlier airborne cycle.

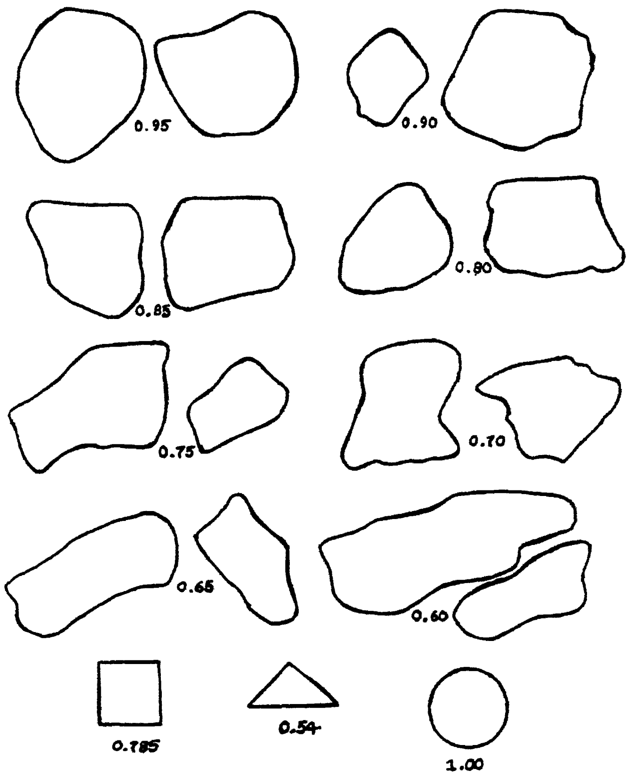

Fig. 5. Mathematical Statement of Sphericity of Two Grains Each of Several Degrees of Roundness with Three Simple Geometrical Forms for Comparison. (9)

The Classification of Sands Based on Origin

A number of classifications of sands based on origin have been made, notably by Sherzer (44) and Grabau. (13, p. 288) The classification by Grabau is the more complete. With the more technical terms omitted, it is given in Table V.

Table V. Classification of Sands Based on Origin (mod. after Grabau)

A. Clastic Sands	
1 Glacial	2 Volcanic
3 Residual	4 Aqueous
5 Eolian	6 Artificial[3]
B. Non-clastic Sands	
7 Organic	8 Concentration (Precipitation, E.R.S.)
9 Snow and firn (névé)[3]	10 Igneous[3]

A brief, but fairly complete, discussion of types 1-5 and 7-8 is given by Sherzer. (44, pp. 628-650)

[3] Added to Sherzer Classification by Grabau. (13, p. 288)

The Production and Uses of Sand

Although, as discussed above, the word sand as a natural product covers merely a given size of grain, under the production and uses of sand a more or less pure quartz sand is implied. In order of amount of production in 1943, the chief uses of sand are listed in Table VI. The value per ton usually indicates the purity (mineralogical or bachteriological) required for a particular use. In the United States, in 1943, some 31,000 men were employed in the production of sand and gravel. This does not, of course, include the large numbers employed in the industries dependent on the sand and gravel.

Usually for *building* and *paving* purposes a sand should be "sharp," (with angular grains) and free of clay and organic materials. Otherwise, a reasonable per cent of quartz, possibly 70 per cent, is the minimum requirement.

Foundry sands (37, p. 749) are the siliceous and other sands used in making forms for casting metals. To the foundryman a "sharp" sand is one that is free of a bond. Naturally bonded sands contain a variable (3-25 per cent) amount of clay. Synthetic foundry sands are mixtures of "sharp" sand with required amounts of clay or bentonite as a bonding material. If used in the cores, the bond may be oil, cereal, resin, pitch, etc.

Table VI. Sand Production in the United States in 1943 (28, p. 1324)

	Production (1)	Price Per Ton	Total Value (2)
Building	30,911	$ .60	$18,662
Paving	23,440	.61	14,305
Foundry	8,925	1.36	12,094
Glass	3,972	1.86	7,377
Engine	2,862	.69	1,983
R. R. Ballast	1,320	.31	412
Abrasive	838	1.71	1,428
Furnace	395	1.37	539
Filter	159	1.63	259

(1) Production in thousands of short tons.

(2) Total value in thousands of dollars.

The important properties are fineness and bonding strength. A foundry sand may contain particles ranging from 3 mm. (granule in the Wentworth classification, Table II) down to clay. The grains may be smooth or rough, clean or stained. Some foundry sands contain compound grains, which have been suggested as possible causes of small explosions in casting. (38, p. 392)

Bonding strength is determined by the amount of clay, the amount of water and the angularity and roughness of the grains.

Sintering Point, the point of incipient fusion, is not now considered by foundrymen to have much importance. *Durability,* life or number of times a molding sand may be used, is much less important than formerly because of the much increased use of the so-called synthetic sands. In fact, some foundries now are even using granite pulverized to the desired fineness with added binder. Foundrymen are also questioning the importance of *permeability* because the gases pass away from the mold face through vents and because it has become common practice to coat the mold face with a clay wash.

In recent years the practice has been introduced of using a sand with a high content of zircon either: (a) throughout, or (b) at points where quick chilling of the cast is important, or (c) as a wash on the mold face. The reasons for this are: (a) the low thermal expansion of zircon as compared with quartz; (b) its high thermal conductivity; and (c) its high melting point (3650° C.—3850°C.).

Glass Sand. (37, p. 754) The requirements for glass sand are a fineness of 100-20 mesh and chemical composition determined by the use to which the glass will be put. Tab. VII gives chemical specifications for four typical uses of glass sand.

Table VII. Specifications for Chemical Composition of Glass Sands (Ries after Weigel)

Quality	SiO_2 Min.	Al_2O_3 Max.	Fe_2O_3 Max.	CaO,MgO Max.
First quality, optical glass	99.8	0.1	0.02	0.1
Fourth quality, plate glass	98.5	0.5	0.06	0.5
Sixth quality, green glass containers and window glass	98.0	0.5	0.3	0.5
Eighth quality, amber glass containers	98.0	0.5	1.0	0.5

Filter Sand. (37, p. 757) Sand is used by communities and large industrial users of water to remove sediment and bacteria. The essentials are: (a) fineness 35-14 mesh; (b) uniformity of size; (c) of such a composition as not to be decomposed or disintegrated by water (high in quartz); (d) shape not flattened or elongated; (e) freedom from organic and bacterial impurities.

A decrease in production of filter sand beginning in 1930 is probably due to: (a) cleaning and re-use of sand; (b) considerable use of granular anthracite coal; and (c) use of a thinner sand bed with gravel beneath.

Abrasive Sand, (37, p. 759) with a wide variety of uses such as stone-sawing, glass-grinding, quartz, garnet and emery papers, and sand-blasting, tends to be replaced by artifical abrasives such as carborundum. For some uses ground-up garnet and emery are preferred.

Where large deposits of garnet sand are available, as at a few localities in Florida, it would seem to the writer that they could be used to good advantage, especially in garnet paper. Size of grain and hardness are the chief prerequisites for use of sand as an abrasive.

Engine Sand (37, p. 761) is used to prevent the driving wheels of locomotives from slipping. The chief requirements are a sand high in silica and of size roughly 80-20 mesh.

Furnace Sand resembles fine-grained molding sand and is used to line open-hearth steel furnaces. It may run as low as 80 per cent quartz and, if lacking in a clay bond, plastic fire-clay is added.

Oil- and Gas-Sand

One of the prime prerequisites for the economic concentration of oil and gas is a reservoir rock. This is usually called oil- or gas-"sand," although it may be limestone, dolomitic limestone, fractured shale, fault breccia, or porous or fractured igneous rock, as well as sand or sandstone. Until about 1932, it was almost universally believed among oil men and even yet it is frequently stated that the factor which makes the "oil-sand" a reservoir is its porosity. Actually, as pointed out by Nevin, (29, p. 374) "permeability and not porosity is the controlling factor." "Aside from the fact that a substance must be porous to be permeable, porosity and permeability have no relation. A sand with low porosity may have relatively high permeability, and the high porosity of many shales (30-40 per cent) is coupled with a very low permeability. The porosity of an oil sand is the ratio of the pore space to the volume of the sand."

The Handbook of Foundry Sand Testing, 5th Edition, (p. 26) defines permeability and discusses the determination of the "permeability number" specifically as it applies to foundry sands, but actually as it applies to the study of permeability of a rock wherever such information is desirable.

Permeability is the physical property that permits the passage of gases or fluids. Sands and sandstones are tested for the permeability number with an air-flow apparatus. The permeability number is the volume of air in cc. that will pass per minute under a pressure of one gram per sq. cm. through a specimen one cc. in volume.

$$P = \frac{v \times h}{p \times a \times t}, \text{ when}$$

P = permeability number
v = volume of air in cc.
h = height of specimen in cm.
p = air pressure in cms. per sq. cm.
a = cross-sectional area of specimen in sq. cm.
t = time in minutes.

Standard testing methods require 2,000 cc. of air to be forced through a specimen 5.08 cm. in height and 20.268 sq. cm. in area.

The fallacy (29, p. 374) of considering porosity and permeability as synonymous, or as being interrelated, or of using porosity as a short cut to permeability is indicated by examination of the following data from three tests of the Bradford, Penn., sand by Nutting (31, p. 44) as given by Nevin:

Table VIII. Relation Between Permeability Number and Porosity

Permeability Number	Porosity
A 7.9	15.3%
B 1.1	15.9%
C 1.2	19.4%

Specimen A, with a permeability number of 7.9, has a porosity of 15.3 per cent, while specimen B, with a permeability number of but 1.1, has almost the same porosity as A—15.9 per cent. On the other hand, specimen C, with nearly the same permeability number as B has a porosity about one-fourth greater.

The permeability of an "oil-sand" determines: (a) the correct spacing of wells for complete economical production; (b) the possibility of economical repressuring of an "oil-" or "gas-sand" by delay of drilling the central well in "five-spot" repressuring, if there are permeable streaks in the midst of "tight" reservoirs; etc.

Nevin concludes that, although a thin layer of oil or water is adsorbed by the sand grains, permeability to air gives reliable results, as a similar layer of air is adsorbed by the sand.

Quicksand

From a human point of view, one of the most interesting and important phases of sand is quicksand. Such interest is evinced in its repeated use by the novelist in the development of a plot—"Toilers of the Sea," "Moonstone," "The Bride of Lammermoor," "Assignment to Brittany," "The Hound of the Baskervilles," and "Lorna Doone." It is also the central theme in cartoons such as that in a recent "New Yorker," in which a very English explorer up to his arm-pits in quicksand, looking at his wrist watch, remarks to his compatriot, "Not so *very* quick, it it?"

The economic importance is indicated by the large number of horses, cattle and sheep which are lost each year in quicksand deposits. In one body of quicksand, to which my attention was recently called, three cattle had been engulfed in the last few years. To protect the rest of his herd, the owner spent considerable time drawing logs and brush into this area possibly 150 feet across. (24) It is reported that, through the years, many ships have been swallowed up after running aground on quicksands. In 1875, a train was engulfed after running off a bridge near Pueblo, Colo., and was never recovered, although the quicksand was probed to a depth of 50 feet.

What makes quicksands quick? A remarkable phase of the answer to this question is that the geologist has lain down so comfortably alongside his ignorance of the solution of a problem, at once so full of human interest and economically so important. Evidence of the truth, that the geologist has not solved the problem, is that a careful search of bibliographies of American geological literature, 1785-1941, revealed but one rather brief paper in a rather unimportant geological publication. (6) This paper, on further investigation, presented the theory which seems nearest the truth, but was based almost entirely and without proper credit on a rather obscure set of remarks on four words in a paper on the cost of excavating one level in the Erie Canal.

Before presentation of this theory, a list of other theories with brief discussion will serve to clarify the problem.

Rounded grains. The writer, in common with many others, started out with the theory that quicksand was simply a sand almost entirely composed of spheroidal grains, which, when lubricated with water, would roll out from under the submerging body, permitting it, especially if it struggled, to be engulfed. A number of considerations make this position untenable, the chief of which is the study of sand grains by Ries and Conant (38) which pointed out, after the study and photographing of literally hundreds of specimens of sands and sandstones, that practically never does a sand or sandstone exist with over 50 per cent rounded grains and that, where any considerable per cent of the grains are rounded, it is evidence of the desert origin of the sand. Another question arises—in the case of large bodies, what would become of the sand that rolled out of the way of the body?

Loose-pack-close-pack. A possible answer to this second question was proposed by Bancroft. (1) In places where, due to up-welling currents of water, the sand grains were "loose-packed," that is, grains of roughly equal size were arranged in straight horizontal and straight vertical rows, there would be a maximum of pore-space, approximately 38 per cent. A struggling body would tend to jar these grains into a close-packed arrangement, in which alternate layers would fit down into the hollows between the grains in the layer below, leaving a pore-space of approximately 26 per cent. The difference of 12 per cent would permit entrance of the struggling body. This theory has been accepted by others. Bancroft's failure, however, to find any supporting evidence caused him to abandon the search of what makes quicksand quick.

Other theories have been: a coating of clay on the sand grains to increase the mobility; a similar coating of decaying organic matter; and the presence of mica grains.

In 1927, in the Pan-American Geologist, (6) Burt discussed the origin of quickness in sands, following very closely a discussion by Hazen (15) in 1900. The Hazen discussion dealt with four words, "Quicksand (rounded sand grains)." Hazen picked up those four words from a previous engineering publication and in five pages laid the basis, not only for Burt's paper, but also for present engineering theory on the question.

In brief, the Hazen theory is that quicksand is found where there is a spring with sufficient upward water movement to *lift the sand grains apart,* so that the practical result is that a body goes down into water, somewhat handicapped by sand, rather than into sand lubricated by water. Quicksand is not a material, nor even a type of deposit, but rather a condition of equilibrium, or lack of equilibrium, between the materials of the deposit and the ground-water. Tab. IX is excerpted from the table of velocities of upward moving water necessary for the lifting of quartz grains of given diameter:

Table IX. Velocity of Water Necessary to Lift Quartz Grains Apart

Vel. of Water in ft. per hr.	Diameter of Quartz Grains in mm.
1.5	0.03
4.	0.05
16.	0.10
65.	0.20
148.	0.30
262.	0.40
410.	0.50

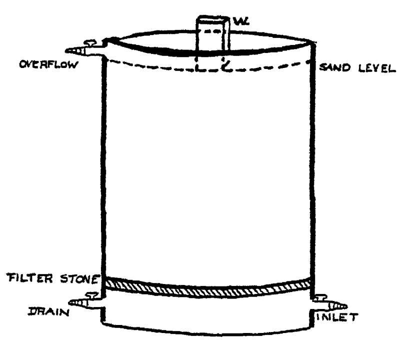

Fig. 6. H. T. Jenkins Apparatus to Illustrate "What Makes Quicksand Quick."

Figure 6 is a sketch of a device by H. T. Jenkins of Cornell University to illustrate the Hazen theory of the cause of quicksand. With dry sand the weight (w) remains in place, no matter how much effort is exerted to bury it in the sand. Even when water is admitted through the bottom inlet valve and the sand is entirely wet, still the weight cannot be buried in the sand. The fact that sand makes a good foundation for a great dam was utilized in the dam over the Mississippi River near Alton, Illinois, where the dam, footings and all, were placed in and on sand. (39) However, when the water is admitted at a rate sufficient to lift the grains apart, the weight buries itself in the sand almost as if it were a person diving into a swimming pool. Then, if the water is shut off and the weight is extricated and again placed on

the sand, the sand is again stable and the weight does not sink in. Sand which had formerly been quick is so no longer, although it feels slightly quick to the fingers.

Table IX also indicates why quicksand is invariably fine grained. Velocities of spring are seldom sufficient to lift any but fine sand grains apart.

A number of questions regarding this Hazen theory arise:

If springs are always associated with quicksand, that fact should be indicated in the summer months by the temperature of the water as compared with the ordinary stream water. Last spring, under the guidance of Mr. J. T. Christie, I located a quicksand deposit on the Heber Ellis farm in Long Branch some four miles west of Greenscastle, Indiana. This quicksand was on both sides of a fence crossing the stream, so that it could be relocated absolutely accurately at a later date. In August, I returned to the place. There was no quicksand; it was gravel; there had been a number of very heavy rains this summer. However, the temperature of the water in the gravel (formerly quicksand) was 3°F. cooler than anywhere else tested in a half-mile of the stream—indicating, it seemed to me, a spring, even though there was no quicksand there in August.

Another question arises: If a spring is necessary for quicksand, how can it be possible that pockets of quicksand vary in position from time to time? The truth of this movement is attested to by several fishermen of my acquaintance. An hypothetical answer is suggested: In two miles of a stream, there are five springs—a, b, c, d, and e. At b and d the sediments are sufficiently fine on May 1 to be quicksand; at a, c and e, there is gravel. Late in May, there is a flood, as a result of which gravel is deposited on all springs but e; so there is no quicksand when the fisherman wades the stream June 1 at either b or d, but there is at e; he decides that the quicksand has moved down from d to e, which it may or may not have done.

Hazen gave as an illustration of sand becoming quick with upward water movement the Western Union Building in New York City. It was constructed with a load of 3¾ tons per sq. ft., safely sustained. Sometime later, wells on adjoining land being pumped began to show cloudiness and the building began to settle. When the pumping was stopped, the building no longer settled.

In addition to the loss of life in quicksand, it also presents a problem which demands the best of the well driller, the builder and the excavation engineer. Prelini (35, p. 188) suggests that the necessary procedure in tunneling quicksand is to drain away the water and prevent the collapse of the sand by strutting the sides with tight boards. In ditching for agricultural tile, a shield may be pushed ahead of the tile to keep the quicksand back. In streams in the cattle-states of the West, where there is abundant quicksand, the cattlemen believe that the quicksand problem can be temporarily solved by driving a herd of cattle rapidly through the quicksand patch, thus packing it down and shutting down the flow of water.

A topic of considerable discussion regarding quicksand is as to whether cattle or men are ever completely engulfed. An article in Science News Letter (42, p. 232) was entitled: "You're safe in quicksand, if you keep still" and presented the following argument: "If you ever have the misfortune to fall into quicksand, don't get panicky and thrash around. If you keep quiet, allow yourself to go down feet first and keep your arms outstretched, you will soon find yourself resting at a depth just below your armpits. . . . You stop sinking when your weight equals that of the quicksand you displace. As a matter of fact, quicksand will support you twice as easily as water." The above suggestion was made by Laurence Pirez, director of the Soil Mechanics Laboratory at Cooper Union, in New York.

Not all soils physicists agree with Pirez. Jenkins contends (19) that the buoyant effects of the quicksand is due only to the water present plus the very slight uplifting by the upward movement of the water.

That the estimate by Pirez was of doubtful validity is indicated by comparison of the two statements—"you will soon find yourself resting at a depth just below your armpits" and "quicksand will support you twice as easily as water." If the latter statement is true, the body would come to rest slightly above the waist instead of just below the armpits.

The advice not to thrash around, thus weakening you, is good, as animals, including man, will drown due to exhaustion, or heart failure may result. As to whether an animal will be engulfed will be determined by the specific gravity of its body.

In the previous discussion, it has been assumed, following Hazen, that the only cause of lifting in quicksand is spring water. Sand grains or any soil particles may be made quick by lifting apart by rising gas. This effect is shown especially in the "cratering" of an oil or gas well out of control. After the crater has been formed by the initial explosion, the gas continues to rise through the soil and changes what had been a sound base for drilling equipment into terrifically quick material which may swallow up hundreds of tons of drilling rig, casing, engine, etc. (14)

Sonorous Sand

Under this name, may be included singing, squeaking and barking sands. I have not tested and see no way to test theories of the cause of these phenomena. Several articles by H. C. Bolton and A. A. Julien toward the end of the last century dealt with theories of causes. (3, 4, 5) Singing sand gives off a sound akin to that of a sawmill; squeaking sand, a rather shrill note; barking sand is described as emitting a hoot-like note as the heel is lifted in walking across the sand, or, if the sand is confined in a bag, when the two ends are folded together. Singing sand is considered by Bolton and Julian to be necessarily dry sand, either siliceous or calcareous, giving off the note on being blown by the wind. Their theory was that all types of sonorousness are due to

thin films of air, as elastic cushions between the grains. These cushions are capable of considerable vibration, thus emitting the sound. Kegel (21) attribues the singing of sand in desert regions to change in position of the constituent grains caused by difference in temperature between day and night. Bolton and Julian state that they have records of over 1,000 localities with singing sand.

Squeaking and barking sands are always moist and lose their sonority on drying. The most famous example of barking sand is on the island of Kauai, Hawaii, (4) but it is reported (33) that much better barking sand is found near Beaufort, N. C. That on Kauai is highly calcareous, the individual grains very angular. (E.R.S.)

Conclusion

Although the path which we have trod is but little of it new, we have built into our route parts from many other trails, and all from whom we have asked help or guidance have been quick to respond. We have not even dodged the quicksands, nor the biological sands, even though full of disease they may be.

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When the Seasons Begin in Indiana

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The conventional beginning dates of the seasons, December 1, March 1, June 1 and September 1, or the "astronomical dates" of the solstices and equinoxes, (December 22, March 21, June 21 and September 22) do not coincide closely with the beginning of the seasons as they are felt in Indiana. The average dates, obtained from the daily temperature normals (average of day and night for many years) are here given for Indiana on several other bases. These dates have real significance and hence considerable interest.

The coldest quarter of the year commences for most of Indiana about December 3. If winter is defined as the season when the temperatures are below freezing, for the average of day and night, it commences in northern Indiana about December 3, in central Indiana about December 15, and in southern Indiana about December 22, except in the Ohio River lowland, where daily normals below 32° are lacking.

If spring is defined as the quarter of the year following the coldest quarter of the year, it commences in southern Indiana about March 1, in central Indiana about March 4 and in northwestern Indiana about March 7.

If spring is defined as the season when the daily normals rise above the freezing point, it commences about February 15 in south central Indiana, about March 1 in north central Indiana, and about March 6 in northern Indiana.

Appreciable plant growth of hardy plants commences when the daily temperature normals rise above 35°. This occurs about mid February near the Ohio River, about March 1 across the southern part of central Indiana, about March 15 in the southern part of northern Indiana.

Mild spring (daily normals rise above 50°) commences about April 5 in southern Indiana, about April 15 in central Indiana and about April 20 in northern Indiana.

The average date of the last killing frost in spring comes somewhat later than the dates just mentioned, when the daily normals rise above 50°. The average frost-free season commences about April 20 in much of southern Indiana, about May 1 in much of central Indiana and near Lake Michigan, but not until about May 7 in considerable areas in the elevated eastern and northeastern parts of the state, and in the northwest away from Lake Michigan.

As corn makes little growth when the temperature is below 55°, the date when the average temperature normals exceeds 55° is of interest in Indiana, because of the local importance of corn. In the southern part of the state "the corn-growing season" commences about April 20, except along the Ohio and lower Wabash river bottoms. In central Indiana it commences about April 25, along the upper Wabash river it

commences about May 1, but in the northern counties not until after May 5.

The warmest quarter of the year commences in most of Indiana nearly a week after June 1. In the northwestern part of the state, however, this warmest quarter does not commence until about June 10.

If summer is defined as the season when the temperatures average 68° or higher, summer commences in the last week in May in the southern fourth of the state, during the first week in June in the central one-fourth of the state and in the second week in June in the northern one-fourth.

Hot summer, that is, averages of day and night together of 75° or higher, commences about June 15 in the southern tier of counties, about July 1 along a line from Cincinnati to Terre Haute, during the first week in July in most of central Indiana and in the second week in July in the northern and eastern part of central Indiana. Daily normals of 75° are lacking in the northernmost counties, despite the fact that they occasionally have very hot days. When however, the temperatures of all the days and nights of 40 years are averaged, the highest total is somewhat below 75°.

The beginning date of autumn depends, therefore, on what criteria are used. Hot summer ends in early August in the part of northern Indiana that attains that level, it ends about August 10 in most of central Indiana, about August 20 in most of southwestern Indiana, but not until about September 1 in the hottest southwestern corner of the state.

The third quarter of the year, so far as temperature is concerned, commences not on September 1 but about September 8 in almost all parts of the state.

If autumn is defined as the season when the daily normal temperatures fall below 68°, it commences for much of northern Indiana about September 5, for much of central Indiana about September 10, for much of southern Indiana about September 20, but not till September 25 along the lower Ohio river bottom.

Cool autumn weather, daily normals below 50°, commences about October 20 in northern Indiana, during the last week of October in most of central Indiana, and during the first week of November in southwestern Indiana.

The season of frequent killing frosts commences about October 10 in most of the northern half of Indiana, and about October 15 in most of southern Indiana.

The average date of the snowfall of measurable amount (not snow flurries) is during the first week of November in northern and northwestern Indiana, about November 10 in most of central Indiana and during the third week of November in extreme southern Indiana. Although the amount of rainfall received in Indiana varies greatly from time to time, the variation is irregular; no particular season normally is especially dry or exceptionally rainy. Hence no discussion of the beginning dates of wet or dry seasons is appropriate here. (For most

of the world such seasons are as real and often much more significant than the seasons based on temperature contrasts.

Further details on the beginning dates of most of the types of seasons here considered, with data on their ending and average lengths, with many maps showing local contrasts within the state, are given in "Climate of Indiana," Indiana University Series 1944, 511 pp. The present summary considers, however, three sorts of seasons not there discussed, and brings together data presented in scattered chapters of that volume.

Summary

If the year is divided into four equal seasons on the basis of normal temperatures, they commence between the common calendar beginning dates and the "astronomical" beginning dates. For each of the seasons, the almost imperceptible break in the temperature curve occurs shortly after the first of the month. Winter commences on December 3, not December 1 or December 22; summer commences on June 7, not on June 1 or on June 21.

When the year is divided into fewer or more than four seasons, their beginning dates correspond only approximately with those just mentioned, and display more regional contrast within Indiana. Temperatures normals below 32° commenced soon after the first of December in northern Indiana but not until about December 22 in southern Indiana. Conversely if spring commences when the temperatures rise above 32°, it begins in early February in southern Indiana but a month later in northern Indiana. Considerable plant growth of hardy plants commences about two weeks later, for most of central Indiana about March 1. Mild spring commences during the first half of April in the southern half of the state, if daily normals of 50° is used as a basis. Most people feel that spring does not really come to Indiana until April. The season normally lacking in killing frosts commences for most of Indiana late in April, but not till May in parts of northern and northeastern Indiana. The season of active growth of corn (daily normals of 55°) commences about the time when killing frosts cease to become normal.

Summer (normals of 68°) commences somewhat before June 1 in southern Indiana but not until the second week of June in the northern half of the state. Hot summer (normals of 75° or higher) commences about the summer solstice in the southern one-eighth of the state, but not until after July 10 in the northeastern third. Autumn, if defined as the quarter between summer and winter in temperatures, commences about September 8. The daily normals fall below 68° in central Indiana, also about September 8, but notably later in the southern and earlier in the northern parts of the state. Cool autumn (daily normals below 50°) commences about a month after the autumnal equinox in northern Indiana, six weeks after in southern Indiana. The season of killing frosts commences about three weeks after the equinox in central Indiana, but four weeks after in southern Indiana. The first snow falls in central Indiana usually during the first week in November.

HISTORY OF SCIENCE

Chairman: JOHN S. WRIGHT, Indianapolis

Dr. W. E. Edington, DePauw University, was elected chairman of the Section for 1946.

A Brief History of the Department of Biology, University of Notre Dame

THEODOR JUST, University of Notre Dame

Faculty and Courses

The University of Notre Dame was founded on the site of an old mission known as Ste. Marie des Lacs (1830) by the Right Rev. E. Sorin, C.S.C., first President, who came here from Mans, France, by way of Vincennes on November 26, 1842. The Legislature of the State of Indiana granted its charter on January 15, 1844. Like other institutions of its time Notre Dame was then largely a liberal arts college. The so-called Scientific Department was not organized until 1864 and recognized as a distinct unit of the University. This department included courses in physics, chemistry, zoology, botany, mineralogy, geology and comparative anatomy.

The formal teaching of biology, however, preceded the formation of the Scientific Department by many years. "Early records show that 'the Council of Professors' on June 7, 1844, appointed Brother Augustine, C.S.C., to teach botany and zoology." The Bulletin for 1859-60 gives the name of J. E. Tallon, M.D., as professor of physiology, anatomy and botany.

In 1863 Rev. Louis Neyron[1] was made professor of anatomy, physiology, and hygiene, but apparently did not begin teaching until the school year of 1866-67. Rev. Thomas L. Vagnier, C.S.C.,[2] was also appointed in 1863 as professor of botany as well as of chemistry and physics.

Thus the formation of the Scientific Department as a recognizable entity in 1864 was a mere formality, as science had been taught under the liberal arts program but the success of scientific subjects warranted their being set apart. Since 1867 all students followed the same Pro-

[1] Rev. Louis J. Neyron, born probably in 1803, in France; missionary and famed physician in Indiana, Illinois, and Kentucky 1836-1863 when he came to Notre Dame; served in various hospitals during the Civil War; Professor of Anatomy, Physiology and Hygiene at the University of Notre Dame since the second session of 1866-1867; died Jan. 7, 1888.

[2] Rev. Thomas L. Vagnier, C.S.C., born March 22, 1839, at New France, near Fort Wayne, Ind.; entered Notre Dame in 1844, joined the community in 1855, Professor of Botany, Chemistry and Physics 1857-1874; died Aug. 1, 1926.

gram of General Science, or sequence of prescribed courses, which was later superseded by five different programs (1907) leading to a Bachelor of Science degree in Biology, etc.

In 1868, when Rev. C. B. Carrier, C.S.C.,[3] succeeded Father Vagnier as professor of botany, he also took over the directorship of the Scientific Department, now known as the College of Science. In addition, Rev. John A. Zahm, C.S.C.,[4] professor of physics, was appointed as assistant director. By that time there were also available four or five competent professors and the scientific course had made an excellent beginning. When in 1874 Father Carrier left for Texas and later for Canada, Rev. Alexander M. Kirsch, C.S.C.,[5] succeeded him and continued in this capacity until 1918. The term biology appears for the first time in the Bulletin of the University for the school year 1894-95, in which Father Kirsch is listed as professor of biology.

In 1870 a "partial course in medicine" was introduced and a medical department was recognized. Originally taught by Father Neyron, these subjects were taken over by local physicians, namely Drs. John B. Berteling, Francis J. Powers and Thomas A. Olney. By 1907 students were privileged to attend surgical clinics in the new St. Joseph Hospital of South Bend, Ind. As early as 1885 medicine was an optional study during the "Post-graduate Course."

The science of bacteriology appears for the first time in the Bulletin for 1879 in a statement that formal instruction in this subject is given and a completely equipped laboratory for the use of students was added to Science Hall in 1886. Also mentioned is a laboratory in photomicrography with an adjoining darkroom. Father Kirsch was the instructor in both of these subjects.

A notable development was the organization by Father Kirsch of the Laboratory of Cellular Biology, which was said to be the first labora-

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[3] Rev. Joseph Celestine Basile Carrier, C.S.C., born July 14, 1832, at St. Jouarre, France; arrived in America in 1855 and at Notre Dame in 1860; Master of Arts and Licentiate of Science; chaplain in Grant's Army from 1863 to 1865; trip to France in 1866; Director of Scientific Department and of the Museum, University of Notre Dame, 1867-1874; President of St. Mary's College, Galveston, Texas, 1874-1876; Professor of Natural Sciences, College St. Laurent, Montreal, Canada, 1876-1904; member of many scientific societies and contributor to various scientific journals; died Nov. 12, 1904, at Montreal, Canada.

[4] Rev. John Augustine Zahm, C.S.C., born June 14, 1851, at New Lexington, Ohio; came to Notre Dame in 1867, was soon appointed Professor of Natural Sciences, Assistant Director and later Director of the Museum; author of many books and articles on scientific subjects (*Evolution and Dogma*, 1896, etc.) and his travels; friend and travel companion of President Theodore Roosevelt, friend of President William Howard Taft; successful lecturer on scientific subjects; distinguished Dante scholar; planned and built Science Hall at Notre Dame; died Nov. 11, 1921.

[5] Rev. Alexander Marion Kirsch, C.S.C., born Sept. 11, 1855, at Clemency, Luxemburg; 1876-1918 Instructor in Natural Sciences, later Professor of Zoology, after 1877 Assistant Director of the Museum and later Director of the Museum; studied cytology at Louvain, Belgium, from 1879-1883; author of contributions to mammalian anatomy (*An Elementary Course in Mammalian Osteology*, Notre Dame, Ind., 1903), botany, cytology (*Cytology, or Cellular Biology*, published in The Microscope, vol. 11, Trenton, N. J., 1891), and mineralogy; died Jan. 15, 1923.

tory of its kind in the United States. Father Kirsch's lectures on this subject were published under the title *Cytology, or Cellular Biology* in the journal "The Microscope" (1891) and given also at the Cold Spring Harbor Biological Laboratory.

In 1904 Rev. Julius A. Nieuwland, C.S.C.,[6] became professor of botany and remained in that position until 1921. A student of the late Dr. Edward Lee Greene,[7] he was instrumental in bringing the latter to the University late in 1914. At that time Dr. Greene transferred his entire botanical library and herbarium to the University, where they are still housed. Dr. Greene's stay at Notre Dame was altogether too brief, as he died the next year, Nov. 10, 1915, and was buried at Notre Dame in the community cemetery. After Father Nieuwland had changed over to the Department of Chemistry the late Rev. W. Albertson, C.S.C.,[8] a former student of Father Nieuwland, took over the teaching of botany and bacteriology until his death in the spring of 1929.

Throughout these years the College of Science functioned in its original organization without separate departments until 1920, when it was reorganized and given its present form. The old course leading to a Bachelor of Science degree was dropped and specialization was required. Owing to the leadership of Father Kirsch the equivalent of the present Department of Biology was functioning long before the reorganization of the College of Science. When Father Kirsch retired in 1918 the late Rev. Francis J. Wenninger, C.S.C.,[9] took over the headship, to which duty he later added in 1923 that of Dean of the College of Science. He held both of these positions until his death on Feb. 12, 1940.

Since Science Hall had become too small, a new Biology Building was erected in 1936 and in the spring of 1937 the Department of Biology moved into it. Much new equipment is being added and all teaching facilities are thus constantly being improved.

So much for the general background of the administrative aspects and the general functions of the Scientific Department and its successors.

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[6] Rev. Julius Arthur Nieuwland, C.S.C., born Feb. 14, 1878, at Hansbeke, Belgium; Professor of Botany at Notre Dame from 1904 till 1921, Professor of Organic Chemistry from 1921 till his death; Dean of the College of Science, 1920-1923; died June 11, 1936; for additional data see Lyon, M. W., 1937—*Father Nieuwland the Botanist,* and for bibliography consult Amer. Midl. Natur. 17 (4): vii—xv, 1936.

[7] Edward Lee Greene, born Aug. 20, 1843, in Hopkinton, Rhode Island; Episcopalian minister and missionary in various western states; 1885-1895, Instructor and later Professor of Botany, University of California; Professor of Botany, Catholic University of America, 1895-1904; Honorary Associate in Botany, U. S. National Herbarium and U. S. Department of Agriculture, 1904-1914; University of Notre Dame, 1914-1915; honorary LL.D. from the University of Notre Dame in 1894; died Nov. 10, 1915; see also H. H. Bartlett (1916) and E. D. Kistler (1936).

[8] Rev. George W. Albertson, C.S.C., born Oct. 1, 1886, near Kalamazoo, Mich.; Professor of Botany and Bacteriology, Dean of the College of Science 1927-1929; died June 7, 1929.

[9] Rev. Francis Joseph Wenninger, C.S.C., born Oct. 27, 1888, at Pamhagen, Austria; Professor of Zoology and Head of the Department of Biology, 1918-1940, Dean of the College of Science from 1923 till 1927, 1929 till his death, Feb. 12, 1940; see also Amer. Midl. Natur. 23 (2): viii pp., 1940.

Let us now consider some of the aspects of the work done in these early days both by students as well as faculty members.

United Scientific Association

The *United Scientific Association,* subsequently known as the *Notre Dame Scientific Association,* was founded on May 12, 1868, with Rev. J. C. Carrier, C.S.C., as President, "for the furtherance of scientific objects." The membership of the association was restricted to "students of the very highest grade." It had three departments, viz., natural history, physics, and mathematics. By Feb. 16, 1869, it had 25 members, 17 of whom were considered active. Its activities included professorial Lectures, debates and lectures by students on scientific subjects, "exploration parties" (now known as field trips). The association also maintained at that time a library of 77 volumes and subscriptions to "three solid scientific periodicals." Its modern equivalent is the *Notre Dame Academy of Science,* founded in 1926 by the late Dean Wenninger. This Academy is likewise restricted to honor students in the College of Science.

Science Museum

In Mr. M. R. Keegan's report of the first commencement at Notre Dame, Aug. 1, 1845, published in the Philadelphia Catholic Herald of Aug. 28, 1845, he reports: "But the greatest rush was to the hall occupied by the splendid museum lately purchased by the institution from Dr. Cavalli, of Detroit, who had been collecting it at great expense for many years. It is a splendid collection of beasts, birds, fishes, reptiles, antiquities, etc., from various parts of the globe."

We also know how the Museum was secured. "Father Sorin owned a couple of lots in that city (Detroit) and made a trade with Dr. Cavalli." In 1865 adequate space could finally be provided for the growing Museum which was placed under the care of Father Carrier, its first real curator. Thus Father Carrier may well be regarded as the founder of the Science Museum at Notre Dame. Among other contributions he made himself by his ardent collecting, he encouraged students to collect for the Cabinet of Natural History and Comparative Osteology or the Mineralogical or the Geological Cabinets. While traveling in Europe in 1866 Father Carrier secured a great deal of material for the Museum, for example as gifts the following items: a six-inch telescope presented by Emperor Napoleon III, over five hundred books and twenty large boxes of specimens. In 1876 the Cabinet contained birds, quadrupeds, stuffed and lithographed in colors, native and foreign plants, in excess of 14,000 specimens. Present were also collections of minerals, fossils from "all geological formations," shells, insects and reptiles, eggs and nests, and Dr. Boyd's large collection of skeletons which had been on exhibition at the Inter-State Exposition in Chicago (1877). Father Carrier himself had collected some 8,000 specimens of plants. In 1876 a Mr. Otto, a professional taxidermist as far as the reports go, came from Chicago to supervise the mounting of some of the specimens. Father Zahm,

Curator since 1874, contributed many items collected by himself and solicited from students and friends. By 1878 the Museum was apparently one of the better collections of its kind at that time. Unfortunately, "In the fire of 1879 at the University the entire collection was destroyed, with exception of a single specimen—a mounted wolf—which had been taken out of the museum for renovation."

The rebuilding of the Museum was begun in 1880. Rev. D. Clarke, of Columbus, Ohio, presented the Museum with a collection of minerals and fossils. Former students and friends continued to send specimens to the Museum and additional purchases helped to restore the lost collections. In 1883 Science Hall was built and the Science Museum was transferred to new and spacious quarters in it. It has been there ever since.

Botanical Garden

In the spring of 1867 Father Carrier laid out a little botanical garden west of the old church, and in 1872 he developed a larger garden at the east end of St. Joseph's Lake. It is quite likely that this larger garden was the first real botanical garden developed in Indiana.

Botanical Collections

(Libraries and Herbaria)

The first major botanical collection of European plants was given to the University by the French botanist Cauvin, for many years President of the French Institute. Another valuable collection of New Zealand plants, principally ferns, was donated by a missionary, Rev. S. Barthos. This herbarium was augmented with American collections by Father Carrier and later by Father Kirsch (since 1874). By 1877 the herbarium contained between 4,000 and 5,000 specimens. Needless to say, this first herbarium was destroyed in the great fire of 1879.

Meanwhile Father Carrier had left the University but had continued his botanical studies in Canada. His work was publicly recognized by the award of a diploma by the Commissioner of the Chicago World's Fair in 1892, and similarly during the same year for a collection of Canadian plants at the Provincial Exhibition of Montreal. These collections are still largely represented at Notre Dame. Father Kirsch too collected with great ardor and added many specimens to the herbarium. Collections of tropical woods and fruits as well as many cryptogams are still housed in the Museum. After 1904 Father Nieuwland began his extensive botanical studies and built up the collections to an unprecedented level. By now this herbarium contains probably more than 50,000 specimens, many of which were received by exchange or gift. At the same time Father Nieuwland built up his rich botanical library with rare acumen and lasting devotion. This library now contains in excess of 3,000 volumes and is still growing.

A proud acquisition was the gift made to the University by Dr. Edward Lee Greene of his treasured library and irreplaceable herba-

rium. These came to the University in 1914 and, by the terms of the gift, must be kept as separate collections. This library is replete with pre-Linnaean works in botany, many of which are beautifully illustrated or otherwise valuable books. All in all, the library contains more than 4,000 volumes. The Herbarium Greeneanum is one of the most valuable collections largely of western American plants. As it includes the majority of types of the numerous new species of American plants described by Dr. Greene, it is indispensable in any serious taxonomic or monographic work. The herbarium is said to contain about 100,000 specimens.

It is worth mentioning in this connection that the Department of Biology has a third library, mainly of zoological and general biological books and journals. All told, some 10,000 books in all fields of biology are thus available for the reader.

The American Midland Naturalist

Founded in April, 1909, as the *Midland Naturalist* by Father Nieuwland at the suggestion of Dr. Greene, the journal was renamed the *American Midland Naturalist* before the year was out. Under this name it has appeared without interruption ever since. In the early years of its existence Father Nieuwland issued with it reprints of rare works in natural history, viz., all by LeConte and Rafinesque. In 1944 a new supplementary series, known as the *American Midland Naturalist Monograph Series,* was initiated by the author.

Conclusion

Much is being done at the present time to increase the facilities of the Department and to enlarge its scope of teaching in the undergraduate and graduate levels. Well founded on its great tradition and aware of progress in the field, the Department looks forward to greater service to Notre Dame and thereby to the Nation.

Acknowledgements

For assistance in locating references and information the writer is greatly indebted to Mr. Chas. C. Deam, Bluffton, Ind.; to Mr. Paul Byrne, Librarian, and Miss Eileen Conley, Reference Librarian, of the University of Notre Dame.

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Living Indiana Scientists, A Statistical Study

H. E. ZABEL and STEPHEN S. VISHER, Chicago, Ill., and Indiana Univ.

The seventh, 1944, edition of "American Men of Science" contains sketches of 655 scientists living in Indiana, 1,288 scientists who were born in Indiana and 1,215 collegiate alumni of Indiana colleges and universities. Indiana universities conferred the doctorate upon 334 scientists and the Masters or Engineering degree upon 172 who have not received a doctorate. These several groups, subtracting duplicates, total 2,304 living Indiana scientists. An additional 349 scientists now living elsewhere were faculty members in Indiana.

Of the 655 scientists living in Indiana in 1943, slightly more than two-thirds are connected with universities and colleges; one-fifth are with industrial firms.

Purdue University with 198 sketched scientists has nearly one-third of the scientists in the state, and nearly one-half of those connected with educational institutions. Indiana University has 97, Notre Dame 39, DePauw 18, Butler 13, Rose Polytechnic 9, Valparaiso 9, Ball State 8, Earlham 7 and Wabash 7. Four colleges have 5 each: Goshen, Hanover, Manchester and Indiana State Teachers. Taylor and Franklin each have 4, Indiana Central and Evansville 3 and Marion 2. Seven colleges have one each (Huntington, Kokomo Jr., Oakland City, St. Francis, St. Joseph, St. Mary-of-the-Woods, and Tristate).

The industrial concerns with most sketched scientists are Eli Lilly 30, Standard Oil of Indiana 29, Commercial Solvents 16, Mead Johnson 9, Servel 7, Pittman-Moore 5, Reilly Tar and Chemical 3.

Indiana has a larger percentage of its sketched scientists employed by industrial concerns than is true for most states, because Indiana is more highly industrialized than are most states.

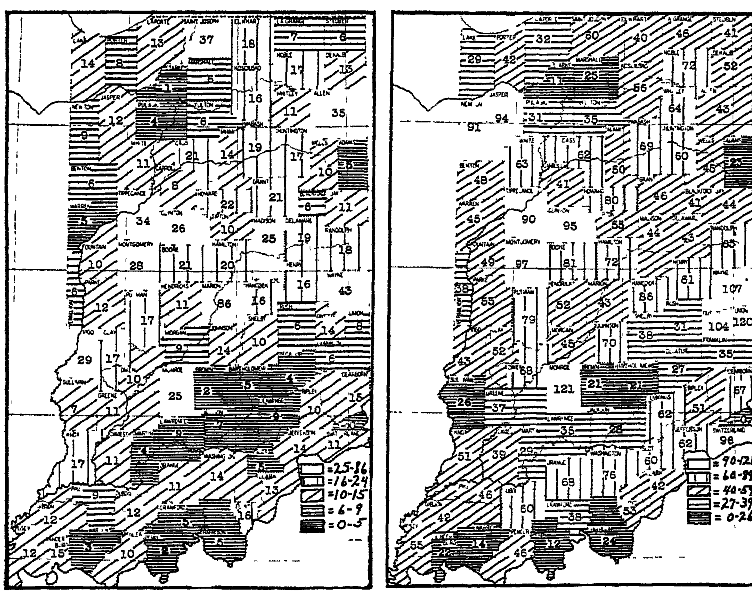
Birthplace of Scientists Born in Indiana

Indiana is given as their native state by 1,288 scientists sketched in the 1944 edition of "American Men of Science." Only six states yielded more, New York, Pennsylvania, Ohio, Illinois, Massachusetts, and Iowa. All but Iowa of these six states have notably larger populations than does Indiana. The states which rank eighth and ninth in the number of native scientists are Michigan and Wisconsin, both of which have about 200 fewer native scientists than Indiana.

Between the 1938 and 1944 editions of "American Men of Science," Indiana increased its contribution of scientists by 15 per cent, a greater increase than that of the total population. At about the average date of birth of the 1938 group, Indiana yielded 473 scientists per million population. For the 1944 group, the yield had increased to 494 per

million. Both of these yield figures are relatively high as compared with the larger sections of the country, except New England. The yield of the South was 173 per million, of the North Atlantic States 400, of the North Central States 448, of the Rocky Mountain and Pacific States 470. Indiana's relatively high yield reflects several conditions, including the presence of relatively few negroes or other colored people, very few of whom have been recognized as scientists.

The birthplace by counties of the 1,265 scientists who gave their birthplace adequately to permit county location is shown on Map 1. The 22 counties which yielded most are Marion with 86, Wayne 43, St. Joseph 37, Allen 35, Tippecanoe 34, Vigo 29, Montgomery 28, Clinton 26, Madison 25, Monroe 25, Howard 22, Cass 21, Grant 21, Hamilton 20, Delaware 19, Wabash 19, Elkhart 18, Randolph 18, Clay 17, Knox 17, Noble 17, Putnam 17.



Map 1. Number of scientists sketched in American Men of Science 1944, born in each county.

Map 2. Yield of living scientists per 100,000 population in 1900 by counties.

Map 1 shows that none of the counties which produced 16 or more living scientists are in the southern part of the state, except Monroe, Knox and Floyd. Conversely most of the counties which yielded fewer than 10 scientists are in southern Indiana, but 10 such counties are in the northwestern part of the state and three in northeastern. Only the smallest county in the state (Ohio) yielded no scientist, and only one other (Starke) yielded only one. Brown and Perry each yielded 2.

In proportion to population at about the average date of birth of these scientists, which was about 1900, the rank of the counties is appreciably different. The 20 highest, in decreasing order, are Monroe, Union, Wayne, Fayette, Montgomery, Switzerland, Clinton, Jasper, Newton, Tippecanoe, Hancock, Boone, Howard, Putnam, Washington, Hamilton, Noble, Johnson, Wabash and Owen.

When mapped (Map 2), it is apparent that the high ranking counties are situated neither near the northern or southern margins of the state, except that Switzerland County ranks high. Three counties that produced more than one scientist per 1,000 of population at about the time of their birth are in the east, Wayne (Richmond) and its southern neighbors. Three other high counties, which produced one scientist to little more than 1,000 people, are Tippecanoe (Lafayette) and two neighbors. Other high counties are Monroe (Bloomington) and Newton, Jasper and Hancock. Most of the counties which produced 69-89 scientists per 100,000 people are close to the most productive counties. Exceptions are Washington (with Salem and Paoli) and Noble, whose noble name may possibly have helped some of its native sons to high achievement.

Five of the ten counties which yielded fewest scientists in proportion to population border the Ohio river. Three others are also in southern Indiana. Northwestern Indiana has, however, two counties which rank low and three others which rank relatively low. The central third of the state, north and south, contains no county which ranks very low and only one (Rush) which ranks relatively low.

These data on the yield of scientists in proportion to population when they were born indicates that the presence of a college where science is valued played an appreciable role. The counties where colleges were conspicuous in 1900 all rank high. Thus, Wayne, Montgomery, Monroe, Tippecanoe counties with Earlham and Wabash colleges, Indiana and Purdue universities, all rank in the upper tenth of the counties in yield. Putnam, with DePauw, also ranks in the upper one-sixth of the counties. Three other high counties are close to Purdue University (Clinton, Jasper, Newton). Another high county (Hancock) although it has no college, is situated not far from several colleges. Switzerland and Noble counties are the most conspicuous exceptions to the rule that the high counties either have a college or are relatively close to one.

Although most of the college influence in increasing the yield of scientists in proportion to population is due to educational stimulation, mention may be made of the fact that quite a number of scientists born in college towns are the children of professors.

Collegiate Alumni of Indiana

The A.B. degree or its counterpart was received by 1,215 persons sketched in "American Men of Science," 1944. Only seven states have more such alumni than has Indiana, namely New York, Massachusetts, Ohio, Pennsylvania, Illinois, California and Michigan. These states all

have considerably larger college populations than does Indiana. It may be noted that Iowa, which was the birthplace of 4 more scientists than Indiana, falls behind Indiana in the number of scientific collegiate alumni. Conversely, Michigan and California, which were the birth-states of fewer scientists than was Indiana, have more alumni scientists.

The fact that Indiana was the birthplace of 1,288 scientists but conferred college training on 1,215 shows that 73 more embryo scientists went elsewhere for their college training than the number that came to Indiana colleges from other states. A comparable situation occurs in several other states, notably New York, Pennsylvania, Iowa, Missouri, New Jersey, Illinois and Kentucky. This shows that Indiana has failed somewhat to afford adequate educational facilities for future scientists, but Indiana has failed less badly than several other states have done. States that have afforded collegiate training to many more than their own native scientists are Massachusetts, California, Michigan, Connecticut and Washington.

The leading Indiana institutions in the collegiate training of these scientists are Indiana University with 331 such alumni, Purdue 253, DePauw 138, Wabash 95, Earlham 71, Valparaiso 64, Butler 54, Notre Dame 42, State Teachers 36, Manchester 22, Rose Polytech 22, Hanover 20, Franklin 14, Indiana Central 11, Goshen 9, Evansville (Moore's Hill) 9, Oakland City 8, Taylor 5, Marion 5, Tristate 4, St. Joseph 2, Huntington 2, Rochester 1.

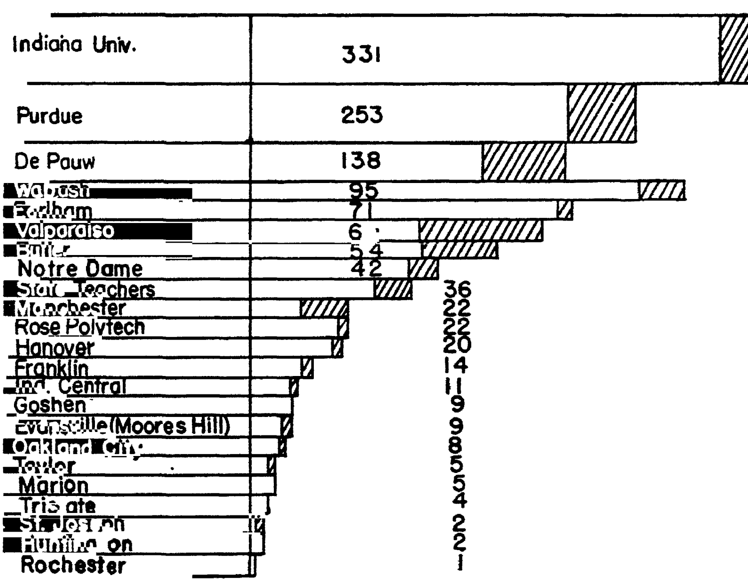


FIG. 3 NUMBER OF COLLEGIATE ALUMNI SKETCHED IN AMERICAN MEN OF SCIENCE 1944

SHADED PART SHOWS THE INCREASE OF 1944 OVER 1938 EDITIONS

In proportion to the number of their alumni, several of the smaller schools, notably DePauw, Wabash, Earlham and Valparaiso, have started more scientists than have either Indiana University or Purdue. This is partly because many Purdue alumni became engineers or farmers, and many Indiana University alumni became lawyers, physicians or high school teachers, a few members of which groups win recognition as scientists.

The increase in the number of alumni sketched in the 1944 edition over the number sketched in the 1938 edition is of interest. Purdue's increase was 44, DePauw's was 35, Valparaiso's 27, Indiana University's 24, Butler's 15, Manchester's 11, Wabash's 10, Notre Dame's 8, State Teacher's 8, and Earlham's 3. (Fig. 3.)

As compared with universities and colleges in other states, five Indiana institutions rank among the nation's leading 100 in the number of college alumni sketched in "American Men of Science" 1944. Indiana University holds 20th place in the nation, Purdue 25th, DePauw 46th, Wabash 66th, Earlham 97th. This is despite the fact that five of the eight universities which rank highest in scientific alumni are situated close to Indiana and are relatively accessible to Indiana students. These five are the Universities of Michigan, Wisconsin, Illinois, Chicago and Ohio with the following numbers of collegiate alumni sketched in "American Men of Science" 1944: 849, 832, 786, 661, 640. Other relatively high ranking schools near Indiana, with the number of their living alumni recognized as scientists, are Michigan State 241, Oberlin 233, Northwestern 186, Cincinnati 133, Ohio Wesleyan 119, Miami 115, Western Reserve 81, Ohio U. 79, Denison 75, Wooster 75 and Case 75.

Specialties of Indiana Scientists

Chemistry has attracted far more Indiana scientists than any other field. About one-fourth of the scientists born in Indiana became chemists, as did slightly more than a fourth of the collegiate alumni; nearly half of those who received doctorates in science in Indiana majored in chemistry. About 30 per cent of the scientists in Indiana in 1943 were chemists.

Physics ranks second to chemistry as a scientific choice, with somewhat more than a third as many devotees. Next comes botany, followed by mathematics, zoology and geology. The numbers in each of these and various other sciences are given in Table I.

Table I reveals that for several sciences, Indiana schools trained more future specialists than were born in Indiana. This was true for botany, plant pathology, pharmacy, anatomy and civil and mechanical engineering. Conversely Indiana has sent to other states for their callege training more future specialists than have trained in Indiana in agronomy, geology, mathematics, entomology, plant physiology, forestry, pathology, medicine, astronomy and chemical engineering. Since considerable numbers of men have been trained in Indiana in these fields without later winning recognition as scientists, it appears that the training was less stimulating in these sciences than in some others.

Among the 334 doctorates received in Indiana by subsequently recognized scientists, there are, in addition to the 151 in chemistry already mentioned, 58 in physics, 19 in zoology, 15 in botany, 15 in geology, 14 in mathematics, 13 in psychology, 13 in pharmacy and 7 in physiology.

The percentages of the scientists sketched in "American Men of Science" 1944 who specialized in each of the more popular sciences has

	Native	A.B. Alumni	Ph. D.	Other Final Degree	Tempor.	Now in Indiana
Chemistry	188	194	71	16	78	105
Phys.Chem.	34	31	22	1	11	22
Organic Chem.	52	54	50	3	15	41
Bio.Chem.	23	24	7	2	3	17
Physiol Chem.	12	8	1		3	4
Agric.	12	7		1	5	4
Agronomy	18	11	1		3	7
Animal Husb.	19	17	1	4	5	11
Physiology	28	27	7	1	3	11
Physics	119	117	58	13	43	55
Mathematics	74	66	14	8	40	54
Geology	52	32	15	4	10	16
Metallurgy	12	13	2	5	5	6
Psychology	57	57	13	2	18	33
Zoology	71	66	15	4	21	28
Entomology	18	13	2	1	9	14
Parasitology	6	5	2			4
Ecology	8	6	1		1	3
Biology	21	17	3	3	7	11
Botany	71	79	14	4	25	31
Plant.Physiol	20	11			4	5
Plant Path.	27	33	4	3	8	11
Horticulture	16	16	1	7	14	7
Forestry	6	3		1	3	3
Anatomy	18	20	1	2	4	7
Pharmacology	16	21	13	5	11	14
Pathology	11	3		1	5	6
Bacteriology	33	31	3	8	10	21
Medicine	32	16		10	3	10
Surgery	9	8		1		1
Med. Miscel.	19	15	1	3	3	5
Genetics	5	4	2		1	7
Soils	5	6	1	1	5	3
Nutrition	10	8		1	7	4
Astronomy	16	13	1	3	3	3
Geography	8	7	1		2	4
Eng. Misc.	29	32	1	14	16	19
Eng. Chem.	24	13	3	4	14	11
Civil	9	13		3	8	4
Elect.	16	15	1	11	7	7
Mech.	16	20	1	17	5	16
Miscellaneous	40	66	1	2	9	10
	1280	1218	334	172	445	655

TABLE 1 INDIANA SCIENTISTS CLASSIFIED BY SCIENCE AND OTHERWISE

been calculated for four other states as well as for Indiana. Some comparisons are of interest. Indiana with 27 per cent who are chemists exceeds Iowa, Minnesota, Massachusetts and Kansas, where from 24 to 19 per cent are chemists. In physics also Indiana, with 9.7 per cent leads.

	Industry	Colleges and Univs.	Governm't	Foundations and Museums	Private	Retired
Chemistry	205	164	39	4	9	4
Phys. Chem.	45	32	2			
Organic	89	49	7	2		
Bio. Chem.	17	26	6	1		
Physical Chem	6	9		1	2	
Agri.	3	14	2		1	
Agronomy		20	9			
Animal Husb.	5	31	3			
Physiology	1	41	1	1	1	
Physics	40	191	18	3	4	1
Mathematics	5	154	1	2	3	2
Geology	16	35	21	1	8	
Metallurgy	12	10	1	3	1	
Psychology	5	105	12		4	1
Zoology	2	108	10	4	5	1
Entomology	3	22	13		1	
Parasitology	1	5	3			
Ecology		9	3			
Biology	1	33	2		1	1
Botany	8	106	13	2	1	1
Plant. Physiol	3	20	4			
Plant Path.	4	34	12		1	1
Horticulture	2	27	8		1	1
Forestry		5	6			1
Anatomy		35				
Pharmacology	14	36	4			
Pathology	3	12	1	2	1	
Bacteriology	21	36	5	5	1	1
Medicine	4	26	5	1	5	3
Surgery		8	1		2	
Med. Miscel.	5	24	2			1
Genetics	1	13			1	
Soils	3	10	5			
Nutrition	3	13	2			
Astronomy		15	2	3	1	
Geography		13	1		2	
Eng. Misc.	20	40	10		7	1
Eng. Chem.	30	13	7	1	1	
Civil	1	21	3			
Elect.	13	22			2	1
Mech.	5	38				
Miscellaneous	4	41	9	1	5	1
	600	1669	254	37	71	22

TABLE 2 INDIANA SCIENTISTS CLASSIFIED BY EMPLOYMENT BY SCIENCES

Each of the other four states have about 6.4 per cent of their scientists in physics. Indiana also leads in botany (7.9), in which science Minnesota, Iowa and Kansas have about 6.5 per cent of their scientists botanists, and Massachusetts 5 per cent. In medicine, Indiana with 3.4 ranks close to Iowa and Kansas but far behind Massachusetts and Minnesota, each of which have 8 per cent of their scientists in medicine. Indiana also is behind in agriculture, zoology and geology. It is about average in engineering and slightly above average in mathematics and bacteriology.

Institutional Connections of Indiana Scientists

Of the 2,653 Indiana scientists here considered, 1,669 or 63.3 per cent were employed in 1943 by colleges and universities, 600 or 22.5 per cent were employed by industry, 254 or nearly 10 per cent worked for the government, 71 were privately employed, 37 were employed by foundations and museums, and 22 were retired. Of the 717 employed chemists, industry took 364, educational institutions 280, the government 54. Of the 256 employed physicists, colleges and universities took 191, industry 40, government 18. Only 5 of the 165 mathematicians were employed by industry in 1943, in contrast to 154 as teachers. Indeed, aside from chemists, physicists, engineers (68), bacteriologists (21), pharmacologists (14) and geologists (16), industry employed few of these scientists. Nevertheless, of the younger scientists, ever increasing percentage are employed by industry. (Table II.)

The 600 Indiana scientists employed by industry are connected with a total of 293 distinct firms of which 221 employed only one each, 32 employed 2 each, 13 employed 3, 7 employed 4, 4 employed 5, 5 employed 6, 6 employed 7-10. Only six firms outside of Indiana employed more than 6 Indiana scientists. These are Dupont 40, Standard Oil Research Co. 14, Dow Chemical 10, American Cyanamide 10, Montsanto 8, Abbott Laboratories 7; companies employing 6 are U. S. Rubber, R.C.A., Bell, Eastman, Alcoa. Only about one-tenth of Indiana's scientists are employed by one of the 13 large corporations which are especially conspicuous for their research activity (recently characterized by Secretary Henry A. Wallace as "dominating industrial research"). Why are not more Indiana scientists employed by these 13?

Age Distribution of Indiana Scientists

The median age of the Indiana scientists sketched in "American Men of Science" 1944 was 47 years in 1944. The oldest 29 were born before 1865, 316 or 12 per cent were 65 or older in 1944 and 7 per cent were 60-64. At the other extreme, 88 were born since 1914. Thus relatively few win the recognition of being sketched in "American Men of Science" before reaching 30. The Indiana botanists are older, on the average, than the chemists, mathematicians, physicists, bacteriologists, pharmocologists or geologists. Conspicuously young as groups are the organic chemists, physicists and geneticists.

Conclusion

Indiana has reared and trained relatively many recognized scientists, and has done conspicuously well with respect to some of the basic sciences. Although Indiana has done better in employing scientists than have many other states, more than half of the scientists reared or trained in Indiana are unable to find suitable employment in this state. This is especially true of the higher types of scientists, those

starred by secret vote of their fellow scientists as especially distinguished. Of this distinguished group, Indiana employs less than one-fifth as many as were born here. (Sixty-one living in 1943 were born in Indiana, only eleven resident here, and of these eleven, five had retired.) Also regretable is the fact that in several of the sciences, Indiana lags badly behind other progressive states. Such a factual presentation as here presented will assist, it is hoped, to correct these conditions.

MATHEMATICS

Chairman: JUNA L. BEAL, Butler University

The MATHEMATICS SECTION met with the Indiana Section, MATHEMATICAL ASSOCIATION OF AMERICA.

Professor H. E. Wolfe, Indiana University, was elected chairman of the Section for 1946.

Statistical methods for controlling the quality of industrial products. IRVING W. BURR, Purdue University.—Since industrial inspection data are statistical in nature, it is only to be expected that they may best be analyzed by statistical methods. The following tools are especially useful: frequency distributions, control charts, correlation and the laws of probability. It is the purpose of this paper to briefly show how these tools are used in practical applications, to suggest this field as a new and attractive career, and to point out that there are many unsolved problems.

Symmetry in metric spaces. PAUL M. PEPPER, University of Notre Dame.—In an abstract metric space S a point c is called a *center of pointwise-symmetry* if for each x in S there exists a point y(x) such that the distance xc equals the distance cy(x) and one-half the distance xy(x). *If* S *has at least* 2 *centers of pointwise-symmetry, then* S *is unbounded.* A point c of S is called a *center of* η*-symmetry* (fractional symmetry) if $0 < \eta \leqslant 1$ and for each x in S there exists a point y(x) for which $xc = cy(x)$ and $xy(x) \geqslant 2\eta xc$. *For each positive* η *less than* 1 *there exist bounded metric spaces of arbitrarily small diameter with* 2 *centers of* η*-symmetry.* (Examples related to the Chebychef polynomials of second kind are shown for each η less than 1.) A point c of S is called a *center of pointwise-open-symmetry* if for each number $\eta > 0$ and each x in S there exists a point $y(\eta,x)$ such that $xy(\eta,x) \geqslant 2xc - \eta$ and $|cy(\eta,x) - xc| \leqslant \eta$. *If* S *has at least* 2 *centers of pointwise-open-symmetry, then* S *is unbounded.*

PHYSICS

Chairman: R. E. MARTIN, Hanover College

Professor K. W. Meissner, Purdue University, was elected chairman of the section for 1946.

Theoretical calculations regarding electron accelerator. E. S. AKELEY, Purdue University.—In the accelerator patented by Hansen in 1937, energy is imparted to an electron by letting it pass a number of times through a cavity resonator. Woodyard thought of modifying this arrangement by placing a number of such resonators end to end and removing the inside end plates, thus forming a wave guide closed at both ends. He showed that electrons of several hundred million volts could be produced, and pointed out that the cost of such an accelerator should increase approximately proportional to the voltage, while the cost of accelerators of the type of the cyclotron or betatron would increase approximately proportional to the cube of the voltage, so that for particles of very high energy, the linear accelerator should be cheaper than the other type.

One of the most important considerations in the design of a linear accelerator is the shape of the cavity, which must produce a longitudinal electric field with which the electron is always in phase. Also the energy dissipation due to the finite conductivity of the walls of the guide should be as small as possible. For this purpose the stationary electro-magnetic modes that can exist between two infinite parallel conducting planes of infinite conductivity have been studied. The relative intensity of the modes excited can be fixed by connecting the planes by a conducting surface of revolution of infinite conductivity. The mode required to accelerate the electrons is the one whose wave length along the axis of the guide is equal to the wave length of the same radiation in the absence of the planes. If only this mode is excited, the conducting surface of revolution must meet the planes at infinity. However, if this mode and one other mode is excited, the surface can be chosen finite. The general character of surfaces of this type are discussed. Numerical integration is used to compute their shape quantitatively and to determine the energy dissipation.

Jet Propulsion. ROBERT D. BECKMAN, Allison Division of General Motors Corporation.—In this paper jet propulsion is shown as a practical application of a fundamental law of physics which has been known for over two thousand years. Several gadgets, model airplanes on a wire, and a small race car on a track feature the demonstrations. Also, a series of slide films designed to give a clear idea of the jet propulsion principle are used.

A Two Meter Grating Spectograph. JESSE B. COON, Bloomington.—A two meter grating spectrograph having an Eagle type mounting has

been designed and built. Some of the mechanical features of the mounting will be described. A method of obtaining a good intensity of 2100A radiation in the fourth order without overlapping will be discussed.

The structure of tellurium as a function of temperature. L. G. DOWELL AND J. ORNDOFF, Purdue University.—Experiments on electrical conductivity, Hall effect and thermo-electric power of tellurium show a behaviour not to be understood on the basis of a simple metal or semi-conductor structure. To investigate this problem in connection with possible changes in structure Lark-Horovitz suggested:

a. Structure investigation of tellurium layers produced and investigated in a high vacuum.
b. Tellurium deposited in a high vacuum but heated in air to various temperatures.
c. Tellurium powder heated in air at 200° and 400°.

The results show that

a. A vacuum deposited layer kept in vacuum all the time shows no change in structure throughout the whole range of temperature investigated.
b. There is no change in the vacuum deposited layer heated in air up to 200°. After heating to 360° in air, new lines appear which are not tellurium but fit some of the tellurium oxide lines or some more complicated pattern.
c. Tellurium heated in air up to 200° shows no change, but after heating to 360° or 400° for an hour and one-half, a whitish deposit appears and the powder then reveals diffraction lines which are identical with the ones obtained under b.

This shows that any theoretical explanation of the electrical properties of tellurium heated in air has to consider the existence of additional layers of material, and electrical investigations of tellurium deposited in a high vacuum and investigated also in high vacuum are necessary to decide the question whether the complicated electrical behavior is due to a complicated structure in the level of electron donators or acceptors themselves, or whether one is dealing with a mechanical mixture of the semi-conductor tellurium and an oxide or other compounds.

Refractions in a Compound Lens. MASON E. HUFFORD.—It is shown that a thick lens can always be found which has the same cardinal points as a comopund lens. The formula of a thick lens is developed using a new algebraic method. New geometric methods of showing the relationships of the cardinal points of a thick lens to its radii of curvature are developed. These relationships are applied in the case of a solid spherical lens.

Electron-diffraction study of the "polish layer." K. LARK-HOROVITZ AND T. S. RENZEMA, Purdue University.—In a study of polished surface we investigated beryllium, boron, germanium and silicon surfaces. We have obtained from these surfaces electron diffraction patterns appar-

ently identical with the patterns obtained from polished metal surfaces by many investigators. Beryllium and boron were chosen by reason of their small atomic radii to challenge the view that the "polish pattern" indicates that the polish layer is an amorphous state of the substrate.

The pattern obtained from polished silicon is not that to be expected from extremely small silicon crystallites nor can it be attributed to SiO_2 amorphous or crystalline. Washing a polished silicon surface in a hydrofluoric acid solution produces a weak silicon powder pattern suggesting the polished surface may be composed of finely divided silicon (insoluable in HF) and materials which are soluable in HF (polishing debris of silica or silicates.)

If a polished silicon surface is heated in air, a surface is produced which is visibly and electrically different from a surface which has been only polished. This surface, however, gives the same pattern as the latter surface even during a progressive removal by etching. Electron diffraction evidence suggests that the heat treatment oxidizes the fine silicon particles which seem to be included in the polish layer. K. Lark-Horovitz and K. W. Meissner have shown by optical methods that the layer formed when polished silicon is heated in air is definitely SiO_2, or a silicate.

Electron diffraction patterns produced by absorbed films of diffusion pump oil and other oily materials have been studied and the effect of rubbing such films observed. Various degreasing solutions and techniques have been tested.

Recent developments in the use of the atomic beam in spectroscopy. L. G. MUNDIE, Purdue University.—With the development of spectral apparatus having a resolving power of several million while still retaining a considerable spectral range, the need for a light source capable of emitting lines of very small width becomes apparent. The atomic beam is ideal for this purpose, for the Doppler broadening may be reduced at will by simply increasing the collimation of the beam. Line widths comparable with the natural width of the spectral line may be achieved in this way.

An atomic beam light source has been developed and is described in some detail. The problem of power dissipation in the grid has been solved by making the elements of fine nickel tubing through which distilled water is forced. The relatively high vacuum needed is achieved by independent pumping of the furnace and excitation chambers.

This apparatus has been used successfully in the case of Sn, Pb, Cd, Mg, Ca, and Al. In the case of Mg the hyperfine structure of many of the lines has been carefully investigated using Fabry-Perot interferometer, and the theoretical interpretation of the results are discussed. Intensity anomalies present within a p-p' multiplet in the case of Mg were not present in the corresponding multiplet of Ca. The investigation of Al by this method presents greater difficulty with respect to furnace construction. While the results are not yet complete, they should be of considerable theoretical interest.

Significance of symbols in physical equations. DUANE ROLLER, Wabash College.—According to Bridgman, physical symbols always denote numbers. Wallot (1926) and Lenzen (1940) are among those who contend that the symbols may represent physical quantities directly. Difficulty in converting certain electrical equations from a rationalized to a nonrationalized form has been interpreted as indicating that the symbols involved must necessarily represent numerical values only. However, an analysis indicates that this interpretation is incorrect. Any physical equation can be written either between physical quantities or between numerical values. The only requirements are consistency and unambiguity in the use of one scheme or the other.

A quantitative method for the spectroscopic anaylsis of potassium-sodium solution. WAYNE SCANLON, Purdue University.—A rapid and accurate method of quantitative analysis of sodium and potassium was developed which gives direct measurements of concentrations ranging from 10 mg/100 cc. to 200 mg/100 cc. The solution containing the sodium and potassium is sprayed into a flame where the resonance lines of these elements alone are appreciably excited. The resonance lines of sodium at 5890 and 5895 A° and those of potassium at 7664 and 7699 A° are separated enough in the spectrum to permit their isolation almost completely by means of color filters. The light from the flame is by this means separated, one color falling on a red sensitive photo-electric cell and other on a yellow cell. The photo electric current is measured by means of a high sensitive galvanometer.

The illumination gas and air mixture that gave the most stable conditions were determined. These could be maintained steady enough to permit calibration of the galvanometer scale in terms of concentrations of potassium and sodium.

The amount of solution required is small, as little as 1 cc. being sufficient. The results obtained on test solutions showed errors not greater than about 3 per cent to 5 per cent.

Some remarks on the focussing of ions in a magnetic field. W. M. SCHWARZ, Indiana University.—The focussing properties of magnetic fields of various shapes are known. In particular the properties of a sector shaped filed have bene worked out by Stephens for the case of electrons. The equations are readily adapted for mass spectrograph work, and some interesting conclusions can be drawn from them after their form has been modified.

Radiation from an Electron Using the Formula, H=Curl Idl/r.

R. R. RAMSEY, Indiana University

The formula, H= Curl Idl/r, which first came to my attention in an article by J. H. Dellinger (Scientific Paper of the Bureau of Standards, No. 354) applies to all aerial circuits used in radio transmission. The thought came to me to see how it would apply to an electron while radiating energy. When applying this formula to a radio circuit we assume that the term Idl/r has the components IdX/r, IdY/r and IdZ/r parallel to the three axes. The curl equation can be written in several ways. I shall write it as follows:

$$H_x = d/dy\ (IdZ/r) - d/dz\ (IdY/r)$$
$$H_y = d/dz\ (IdX/r) - d/dx\ (IdZ/r)$$
$$H_z = d/dx\ (IdY/r) - d/dy\ (IdX/r)$$

Taking the simple case of a vertical aerial the current is all in the Y direction and all terms are zero except the last part of the H_x equation and the first part of the H_z equation. If the point, P, in question is placed in the XY plane the first of these two drops out since z is zero. Since our radio current is alternating current our expression for the current, I, becomes $I_o \sin w(t-t')$, where t′ is the time required for the disturbance to travel from the aerial to the point, P. The time, t′ is equal to r/c. Where r is the distance and c is the velocity of light.

Then H_z or $H = d/dx\ (I_o dY/r) \sin w(t-r/c)$. Since $r=(x^2+y^2+z^2)^{1/2}$ the quantity, x, is involved in r and in differentiating the equation there will be two terms. Differentiating we get $H = -(I_o dy/r^2) \sin w\ (t-r/c) \cos \theta - (I_o dY/r\ wc) \cos w(t-r/c) \cos \theta$.

The first term or the sine term is induction and varies inversely as the square of the distance and is time phase with the current. The second term or the cosine term varies inversely as the first power of the distance. The first term is due to the velocity of the electron and the second term is out of phase with current and may be said to be due to the acceleration of the electron.

It can be shown that these two components have the same numerical value at a distance of $\gamma/2\pi$ from the areial. This is about one-sixth of a wave length and at a distance of a wave length or more the field is all radiation since for practical purposes induction is zero in comparison.

We may assume we have an electron vibrating harmonically in the Y, or vertical direction at the origin of the axes. The charge, e=Idt. Multiply both sides by dl and divide both sides by dt and we have, e dl/dt=Idl. Or Idl=ev. Where v is the velocity of the electron. If the electron is vibrating we have, $v=v_o \sin wt$ at the origin and $v=v_o \sin w(t-r/c)$ at the point, P.

Differentiating this last expression with respect to t we get the acceleration, $a = v_o w \cos w(t - r/c)$.

If one substitutes ev_o for $I_o dl$ and a for the above expression in the last half of radiation term of the above equation for the field, H we get, $H = (ea/rc) \cos \Theta$ as the expression for the magnetic component. Since in e. m. c.g.s. units the electric field component, $E = Hc$, we have, $E = (ea/r) \cos \Theta$. Since energy density is equal to $(1/4\pi)HE$, we have $(1/4\pi)\ (e^2a^2/cr^2) \cos^2 \Theta$ for the energy per cubic centimeter. It will be apparent that the energy radiated or the field is symmeterical about the Y axis.

The energy radiated in one second will be located between a sphere of radius, r and a concentric sphere of radius $(r+c)$. The value of this energy radiated per second can be obtained by integrating over this volume the energy density as expressed above times dV. Where $dV = r \cos \Theta\ d\phi\ r d\Theta\ dr$.

Making the substitutions and indicating the integrations between the proper limits we get,

$$\text{the energy, } W = (1/4\pi)\ (e^2\ a^2/c) \int^{2\pi} d\Theta \int_{\circ}^{\pi/2} \cos^3\Theta\ d\Theta \int_{\cdot} dr.$$

Integrating with respect to ϕ between limits we get the expression multiplied by 2π. Integrating with respect to r we get the expression multiplied by c, when limits are used. Integrating with respect to Θ we have for the upper hemisphere,

$$W = (1/2)\ (e^2a^2) \int^{\pi/2} (1 - \sin^2) \cos \Theta\ d\Theta = (1/2)\ (e^2a^2) [\sin O - 1/3 \sin^3 O]_{o}^{\pi/2}$$

$= 1 - 1/3)\ (e^2\,a^2)$ for the half sphere. For the total energy we have $W = 2/3\ (e^2\ a^2)$ ergs per second as the rate of radiation. Here e, is expressed in e.m. c.g.s. units. If e is expressed in e.s. c.g.s. units we have $2/3\ (e^2\ a^2/c^2)$.

J. J. Thomson "Electricity and Magnetism," p. 61, gives values for E and H which if integrated as above gives this result. Richardson "Electron Theory" p. 258 gives $e^2\ a^2/6\ c^2$. Dull and Plimton "Elements of Electro Theory" p. 167 gives $2/3(e^2a^2/c^3)$.

PSYCHOLOGY

Chairman: W. N. KELLOGG, Indiana University

Professor C. C. Josey, Butler University, was elected chairman of the Section for 1946.

Action potential measurements from the arms in the foreperiod of reaction time to visual stimuli. WILLIAM ARNOLD LIVINGSTON, Indiana University.—Evidence has been reported by other authors both for and against the existence of changes in action potentials during the warning-stimulus interval in the reaction time experiment. Data reported arise from investigation of action potential changes in the interval between the ready signal and stimulus presentation under conditions of simple and choice reaction time to visual stimuli. Work is a contribution to the physiological psychology of simple and complex set.

The relationship between perceptual span and rate of reading. JEAN SUTHERLAND, Butler University.—The purpose of this investigation was to determine (1) the relationship between perceptual span and rate of reading; and (2) the effect of systematic training in perceptual span upon rate of reading and upon improvability in rate of reading. A subsidiary objective of the investigation was to determine the relationship between perceptual span and rate of perception.

Perceptual span was determined by a test consisting of 228 words and phrases presented one word or phrase at a time by means of a tachistoscope. The exposure was 100ms. The reliability coefficient of the test was .93. Correlations obtained between perceptial span and rate of reading as measured by three tests ranged from .31 to .37. Perceptual span and rate of perception correlated to the extent of r=.73. The subjects were 125 college students.

Two groups of university freshmen (N=36) were given training in perceptual span by the same method as the testing procedure described above, although different words and phrases were used. As a result of training the subjects made significant improvement in span and subsequently showed a significant gain in rate of reading. Thereafter this group of subjects was given training in reading, chiefly by the use of the Harvard Reading Training Films. Their progress was more rapid, presumably because of their prior basic training in perceptual span, than that of control groups that did not have this basic training.

Modification of Reflex Behavior in Spinal Dogs

JAMES DEESE AND W. N. KELLOGG, Indiana University

The first indication that relatively permanent changes in reflex behavior can take place in spinal preparations, aside from the effects of fatigue, was found by Prosser and Hunter (2). Following complete spinal transection of laboratory rats they found various spinal reflexes could be extinguished with stimuli repeated at intervals of from 10 to 15 seconds. The extinction was considered to be a central process. The process involved the gradual dropping out of "active units" and the diminution in the duration of the response. This was thought to indicate that extinction was a gradual lowering of the excitability.

Shurrager and Culler (4) reported the establishment of a conditioned response in the spinal dog. The spinal cord was completely severed near the third cervical vertabra. Both semitendinosus muscles (S-T MM.) were exposed and freed of fascial attachments, and then fastened to recording tambours. The conditioned stimulus, either mechanical or electric, was administered to the tip of the tail. It consisted of three short shocks or pressures given one second apart, the third one being presented simultaneously with the unconditioned stimulus. The unconditioned stimulus was a shock of sufficient intensity to evoke a full contraction of the left S-T M. when applied to the left paw. A conditioned response to the conditioned stimulus appeared within 25 to 50 trials (4). "The CR is much smaller than the UCR and is generally confined to a small area near the peripheral end of the muscle. The right muscle remains flaccid throughout" (4). Repeating the conditioned stimulus without the unconditioned stimulus resulted in extinction (3).

Pronko and Kellogg (1) found that there are two types of conditioned responses in shock-shock conditioning. One of the types of response having a much shorter latency is similar to the "conditioned response" observed in spinal dogs by Shurrager and Culler. This response, of smaller magnitude and briefer latency, does not conform to the more typical frequency curves of conditioned responses. It rises to a relatively high frequency early, but then does not increase much. This type of response was characterized by the authors as "a kind of flexing jerk or muscle twitch" (1) appearing in the limb to be conditioned shortly after the conditioned stimulus. This muscle twitch is distinctly different from both the unconditioned reflex and the conditioned reflex of the more usual type. Wendt (5) earlier reported a similar condition in conditioning the knee-jerk in human beings with the unconditioned stimulus being a blow to the limb opposite the one to be conditioned. This is, of course, analogous to shock-shock conditioning. The author interprets the bilateral type of response as being mediated by "a lower level integration." (5) This integration is thought to be already present before conditioning as revealed by the strong

facilitating effect of a blow to one knee on the response of the opposite knee. In an occasional individual a crossed-extension reflex is present instead. Repetition of the conditioning trials increases the bilateral secondary response more than the crossed-extension. The presence of the crossed-extension response in this type of conditioning bears important relation to the finding of the present study.

Operation and care of the animals. The use of morphine sulphate or other depressing drugs was strictly avoided, and ether alone was employed as the anesthetic agent. The purpose of this technique was to permit recovery from the anesthetic as quickly as possible. A skin incision about 3 inches in length was then made at the level of the third lumbar vertabra. The muscle tissue was incised by electrosurgery and the spinus and transverse processes of the spinal column were removed by rongeurs. The vertebrae above and below the third lumbar nerves were drilled with a dental burr and the dura exposed for a distance of about an inch. The cord was ligated in two places to prevent the loss of spinal fluid and was then completely transected between the ligatures. Sulphanilimide was placed in the wound and the muscle tissue and fascia were closed with interrupted silk sutures.

Since the animals were kept for about three weeks following the operation it was necessary to build a special device for keeping them active and healthy. A system was finally arranged which permitted a maximum degree of freedom without danger of the animal irritating his wound, or otherwise damaging himself. When not in the conditioning stock the animals were supported in a canvas sling attached to a metal frame from above. This could be raised and lowered, permitting the animal's legs to be on a level with the body or suspended from above, as needed.

Conditioning technique. Four animals were used in the experiment. Shock-shock conditioning was used in the following manner: Two conditioned stimuli were administered to the left rear paw, one second apart. The unconditioned stimulus was administered to the right rear paw one second after the last conditioned stimulus. All measurable upward changes in contour on the kymograph record occurring 9/5 of a second after the conditioned stimuli and before the unconditioned responses were considered conditioned responses in the animals before the operation. Frequency, latency and amplitude were measured in sessions recorded before the operations. Following the operation all changes in an upward dirction in the right rear leg simultaneous with the conditioned stimuli in the left rear leg were classified as "bilateral flexion" responses. All changes in a downward direction in the right leg simultaneous with the conditioned stimuli in the left rear leg were classified as "crossed-extension" responses. Only frequency of these responses was measured, since latency and amplitude were for all purposes the same throughout.

Results and discussion. Prior to the operation all four dogs were given extensive conditioning training, all animals but one reaching the criterion of 100 per cent frequency of conditioned responses in a 20

trial series. One animal, M74, reached only 85 per cent frequency on the last series. All the animals except M74 had previously been trained in this same conditioning technique, so the frequency on the first series represents retention over varying periods of time. M74 had been previously trained in a slightly different technique. Table I shows the percent frequency on each series for all four dogs. Following the operation

Table I

The Percent Frequency of Conditioned Responses in Right Rear Leg for Pre-Operative Training in all Four Dogs

Series	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
F54	70	60	95	50	50	55	100	100							
M74	45	20	45	55	30	65	80	85	70	60	75	95	75	70	85
M77	95	65	35	55	90	100									
M79	90	100	80	90	100										

1,000 trials were given to each dog, 100 trials on every other day. This necessitated keeping each dog for a period of about three weeks. After the operation the conditioned responses developed during the course of the pre-operative training disappeared. However two distinct kinds of responses appeared in the course of time during the presentation of the conditioned stimuli after the operation. One was a minute muscle twitch or bilateral flexion to the conditioned stimuli, bearing close resemblance to what Shurrager and Culler (4) called a conditioned response in their preparations. The other was a crossed-extension reflex to the conditioned stimuli. These two responses were mutually inhibitory to any given stimulus, but both appeared frequently in the same series. When the frequency of each was plotted graphically it did not resemble a conditioning curve, since both responses appeared and disappeared during the course of the experiment. This may be gathered from Table II and III. However they never appeared immediately on the first trials following the operation in any of the dogs.

In interpreting tables II and III one should consider the mutually inhibitory nature of the two responses to any given stimulus. Under the present conditioning procedure the crossed-extension reflex to the conditioned stimulus was not eliminated as it was in the Shurrager and Culler studies (3, 4). It is possible that the bilateral flexion response might have developed more characteristically if the crossed-extension reflex to the conditioned stimulus had been eliminated.

When the percentage frequency of the two responses are combined it suggests the development of a conditioned response of very low frequency. Table IV gives evidence of this. To the 17th series the frequency rises in a fairly regular fashion, after which it declines slightly to a more or less level position. It is extremely difficult to account for this unless one assumes a gradual restoration of physiological function following the operation. It will not do to attribute it to a gradual "spread of excitation" since there are distinctly two responses present,

Table II

The Frequency of Bilateral Flexion Responses in all Four Dogs Combined Following the Spinal Transection

Series	Per cent	Series	Per cent
1	0.	26	10.
2	3.76	27	21.2
3	7.5	28	13.5
4	0.	29	15.
5	1.25	30	10.
6	2.5	31	7.5
7	6.25	32	12.5
8	3.76	33	3.76
9	2.5	34	1.25
10	1.25	35	2.5
11	12.6	36	0.
12	21.2	37	2.5
13	13.5	38	5.
14	17.5	39	0.
15	12.5	40	1.25
16	0.	41	3.76
17	1.25	42	1.25
18	3.76	43	1.25
19	2.5	44	0.
20	5.	45	0.
21	1.25	46	2.5
22	1.25	47	2.5
23	0.	48	2.5
24	2.5	49	2.5
25	0.	50	2.5

now one appearing now the other. It is quite possible that one response is "inherent" to particular structural limitations here (the crossed-extension) and that the other (bilateral flexion) develops during the process of repeated stimulation. However the functional nature of most spinal reflexes makes an explanation of the *raison d'etre* extremely difficult. An explanation would be much easier if the bilateral flexion responses were isolated instances appearing in one preparation, or if they had not appeared under the same stimulus conditions in an intact animal (1). But there is no doubt of their genuine character and the fact that they are unstable (appearing and disappearing) reflexes, though the stimulating conditions remain essentially the same. The most likely hypothesis seems to be that they represent a kind of spinal analogue of startle responses in intact animals. Such an explanation would leave the role of the unconditioned stimulus doubtful. Shurrager and Culler (3,4) emphatically point to the role of the unconditioned stimulus in the appearance of these spinal "conditioned responses" since they are subject to extinction with the elimination of the unconditioned stimulus.

Table III

The Frequency of Crossed-Extension Responses in all Four Dogs Combined Following the Spinal Transection

Series	Per cent	Series	Per cent
1	0.	26	2.5
2	0.	27	2.5
3	0.	28	1.25
4	0.	29	1.25
5	0.	30	1.25
6	0.	31	7.5
7	2.5	32	11.2
8	8.75	33	7.5
9	20.	34	16.5
10	25.3	35	10.0
11	22.5	36	15.0
12	10.	37	15.0
13	8.75	38	22.5
14	8.75	39	21.2
15	28.8	40	3.76
16	32.5	41	17.5
17	25.	42	12.5
18	27.5	43	22.5
19	20.	44	16.2
20	13.7	45	7.5
21	8.75	46	13.7
22	13.7	47	16.2
23	8.75	48	20.0
24	13.7	49	16.2
25	12.5	50	15.0

To define "operationally" the appearance of such responses as a conditioning process is easy enough, but it leaves much to be desired. In the present study the responses developed, taken together, seem to bear no particular relation to the appearance of the unconditiond stimulus, but seem to depend entirely for their appearance on the conditioned stimulus. The bilateral flexion reflexes isolated may bear a more direct functional relation to the unconditioned stimulus, but in working with the particular arrangement of shock-shock conditioning used in this experiment it is impossible to eliminate the crossed-extension reflex and still keep the limbs of the animal intact. However, the appearance of both of these "muscle-twitch" phenomena seem to indicate a decided modification of reflex activity as stimulation is continued. However, if they are conditioned responses, as defined not only by the experimental procedure, but also by the measuring techniques used, then they are of a doubtful nature.

This bilateral flexion response seems to stand more or less in between the less variable type of response, such as a direct unconditioned response, and the modified or conditioned response. Modification

Table IV

The Combined Frequency of Bilateral Flexion and Crossed-Extension Responses in all Four Dogs Combined

Series	Per cent	Series	Per cent
1	0.	26	12.5
2	3.76	27	23.7
3	7.5	28	14.75
4	0.	29	16.25
5	1.25	30	11.25
6	2.5	31	15.0
7	8.75	32	23.7
8	12.51	33	11.26
9	22.5	34	17.45
10	26.55	35	12.5
11	35.1	36	15.0
12	31.2	37	17.5
13	22.25	38	27.5
14	26.25	39	21.2
15	41.3	40	5.01
16	32.5	41	21.26
17	26.25	42	13.75
18	31.26	43	24.75
19	22.5	44	16.2
20	18.7	45	7.5
21	10.0	46	14.95
22	14.95	47	18.75
23	8.75	48	22.5
24	16.2	49	18.75
25	12.5	50	17.5

of behavior here has taken place, but the frequency and temporal location were not predictable from any previously given conditions. The exact physiological conditions involved in this modification of response are unknown, and speculations are of little avail in the face of the complexity of the structures involved. However, the common conception of the stereotyped reflex behavior, unmodifiable except for diminution or disappearance upon repeated stimulation, seems seriously in need of revision. Whether the modifiability of the responses may be considered conditioning is another question. Certainly the status of the conditioned response, defined by its investigation, has yielded nothing directly comparable.

Summary. Reflex phenomena similar to the spinal conditioning reported by Shurrager and Culler (4) was found in four dogs after the spinal cord had been completely severed at the level of the 3rd lumbar vertabra. These responses were minute twitches in the limb contralateral to the limb in which the conditioned stimuli were delivered, being the same limb in which the unconditioned response appeared. These responses were intermingled and apparently inhibited by crossed-

extension reflexes to the conditioned stimuli. Both responses appeared, disappeared and reappeared in no regular sequence. There was no indication of incipient avoidance movements to the unconditioned stimulus, though all dogs had been trained to a high degree of proficiency in shock-shock conditioning before the operation. Whether this modifiability of response can be classified under the more customary canons of the conditioned response is doubtful. Rather these reflexes may represent a transition between the clear cut cases of learned responses and those reflexes which are relatively invariable and tied up with the existence of certain crucial structures.

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Retention of Nonsense Syllables over Short Intervals of Time

G. RAYMOND STONE, Indiana University

To those studies which have indicated the methodological inadequacy of the deductive type of theory proposed by Hull (3) for rote learning,* the present study should be added. The problem here is the investigation of the phenomenon of reminiscence and its measurement by latency as well as recall values, a problem occupying a central role in the Hull system.

Twenty-four college student subjects learned serial lists of 12 nonsense syllables by the anticipation method with a two-second rate of exposure per syllable, six seconds between trials. Each subject learned comparable lists under four counterbalanced experimental conditions and after two periods of practice learning. Each of the six sessions were one hour in length and on successive days. The control condition was continuous learning to two perfect recitations in succession. In the experimental conditions, rest pauses of two, five, or 20 minutes were inserted after partial learning: the first trial on which seven or more syllables were anticipated correctly. The subject named colors on specially prepared cards during the interval of no learning.

The latencies of the subject's responses were recorded kymographically through a microphone and amplifier system to signal markers which were reset by the mechanism of the drum turning. Complete verbal anticipation data were taken.

Results

The total number of correct responses on that trial in the control condition which followed the first trial having seven or more correct is used as the basis for comparing the recall scores in the experimental conditions after the insertion of rest periods. If reminiscence is present, the first recall trial of the experimental condition(s) must have a reliably greater value than the comparable trial in continuous learning. The data are presented in Table I.

The small increase in the mean recall score of the two-minute rest condition (2 in Table I) over the control condition (0 in Table I) is extremely unreliable and is not present at all in the five-minute rest condition (5 in Table I). Reminiscence, therefore, has not been demonstrated by mean recall scores under conditions supposedly optimal for its appearance (2, 6). This may well be merely a function of the high variability of scores and does not rule out the validity of the phenomenon.

* The present experiment is part of a larger work the remainder of which has been published elsewhere (5).

G. O. McGeoch (4) has suggested that mean recall scores may obscure the reminiscence effect because the subjects who gain in recall do not gain as much as an occasional subject may lose. She suggested a comparison of the number of subjects showing improvement with the number showing forgetting. An analysis of this type is presented in Table II. Although the evidence for reminiscence is supported by these data, the percentage differences lack statistical reliability.

Of all the suggested measures of reminiscence, the latency of response appears to be the most inadequate. Not only is the commensurable range of this variable extremely short (two seconds in this experiment), but it is also subject to a number of determining conditions other than positive excitatory strength which Hull assumes as its major correlate. In any time controlled serial task involving subject reaction to material exposed for limited intervals, there is certain to be an influence of refractoriness to repetition as well as one attributed to the rhythm of presentation-response and its disruption. Both of these influences would tend to distort the latencies of the last portions of a serial task in the direction of greater latencies even though it is a well established fact in serial learning that excitatory strength increases from just past the middle to the end of the series.

Table I

Recall Scores on the First Trial After the Criterion of Partial Learning

	Experimental Condition			
	0	2	5	20
Mean recall	6.75	6.83	5.58	4.00
SEmean	.30	.30	.35	.25

	Mean Difference	S.E. mean diff.
Between 0 and 2	.08	.44
Between 0 and 5	1.17	.43
Between 0 and 20	2.75	.34

Table II

Number of Subjects Showing Improvement on the First Recall Trial After Partial Learning

	Experimental Condition			
	0	2	5	20
Recall Improvement	4	8*	3	0
Decreased Recall	12	8	18	24
Remained Same	8	8	3	0

* When improvement for the control and 2 condition are expressed as percentages, the percentage difference is .166; its S.E. is .123. N = 24.

If rest pauses are introduced, it is to be expected that latency values will recover to some extent but less in the latter portions of the series. This is contrary to the predictions of Hull who would have latency scores parallel those of excitatory strength as measured by recall successes in the series. The relevant data for recall scores on the first trial after rest are presented in Figure I, where the total number of recall failures are plotted as a function of serial position.

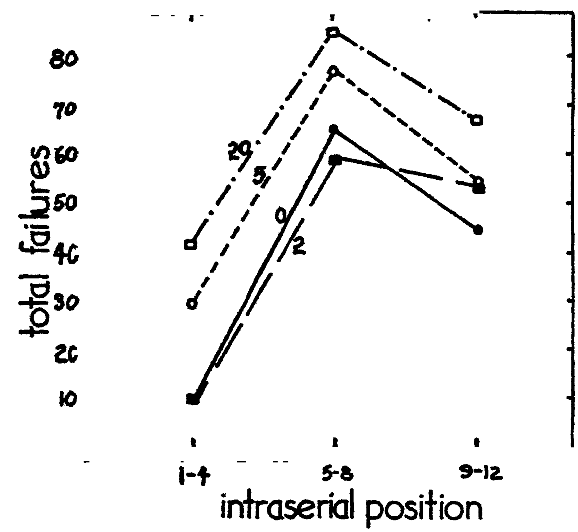

Fig. 1. Recall Failures as a Function of Serial Position. Grouped Data.

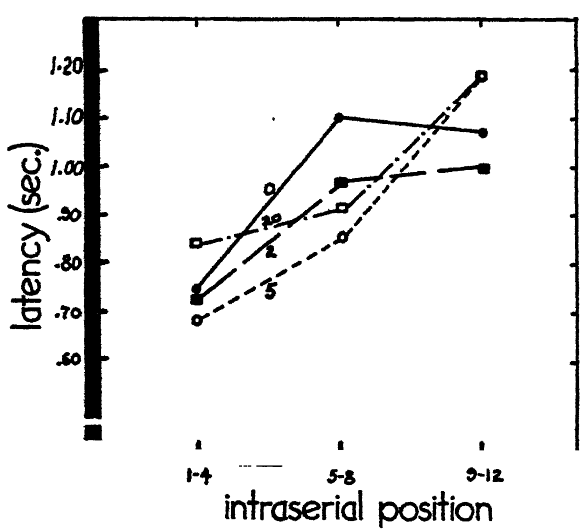

Fig. 2. Latency as a Function of Serial Position. Grouped Data.

The expected increase in excitatory strength in the latter portions of the series (as measured by decrease in recall failures) is evident. The control and 2-minute conditions are not reliably different.

In the case of latency values, however (Figure 2), it is to be noticed that latencies increased in the later serial portions in all experimental conditions even though they were shortened in the middle portions. The fact that the 20-minute rest condition is superior to the control reaffirms the view that latency values are determined primarily by factors other than excitatory strength; no one, to the writer's knowledge, has ever claimed reminiscence (under conditions similar to those used here) as late as 20 minutes after the cessation of formal practice (1).

Before latency values are used in the intricate machinations of deductive theory as a measure of the dependent variable (learning), it seems that a more exhaustive examination of that supposed dependent relation is in order. The present results indicate that latency may be an entirely different function of time interval duration than it is a function of excitatory strength as measured by recall.

Summary

Under experimental conditions supposedly optimal for the production of reminiscence—i.e., nonsense material exposed serially at a two-second rate, learned by the anticipation method, and with rest pauses of two and five minutes inserted after partial learning—the phenomenon was not reliably demonstrated by any of three techniques of measurement. The force of this conclusion is somewhat mitigated by the high variability of the data. It is suggested that latency of response is a poor variable to use as a measure of the dependent variation of learning behavior.

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ZOOLOGY

Chairman: W. R. BRENEMAN, Indiana University

Professor H. H. Vogel, Jr., Wabash College, was elected chairman of the section for 1946.

Determination of the life history of *Cercaria szidati*, a furcocercous larva of the Vivax type. DORCAS J. ANDERSON, Purdue University.—Further studies on *Cercaria szidati* Anderson, 1944, have revealed that the larvae penetrate and encyst in the muscle tissue of minnows, especially in the tail region. Several groups of newly hatched chicks were fed heavily infected minnows. In one series of five chicks, immature flukes were recovered five hours after feeding, and in another similar series, all chicks were passing fluke eggs three days after feeding. Two of the five were sacrificed and found to harbor 14 and 30 sexually mature worms respectively. The remaining three lost the parasites in less than a week. A Great Blue Heron nestling was infected to provide a continuous source of eggs for study of the miracidium. The adult worm is a species of *Linstowiella* similar to *L. viviparae* as described by Szidat, but the morphology of the cercaria and the type of second intermediate host show that the species are distinct. The life history is of interest since both the cercaria and adult are monostomes, whereas closely related species are distomatous.

Gonad stimulating hormones from the anterior pituitary gland and other sources. W. R. BRENEMAN, Indiana University.—Three major sources of gonadotropins have been recognized in vertebrates, (1) implants of the anterior pituitary gland or extracts of this gland, (2) urinary extracts and (3) blood serum. Preparations of the pituitary gland have been referred to generally as the A. P. (anterior pituitary) substances and those from other sources as the A. P. L. (anterior pituitary-like) hormones. The protein nature of all these gonadotropins has been well established but many complicating factors still prevent their exact chemical and biological determination. This is illustrated by the fact that only one of these has been prepared in pure form, by differences in the physical and chemical nature of substances which have been shown to have the same physiological action, by physiological differences between extracted hormones and the secreted ones and, finally, by the incomplete understanding of pituitary changes during the life cycle of any organism.

The concept of the anterior pituitary as the "master gland" or as a producer of "trigger hormones" which stimulate the release of "target hormones" from other sources has been an over-simplification. The anterior pituitary is influenced by gonad, thyroid and adrenal hormones as well as by variations in light and nutrition. Illustrations in the chick demonstrate that there is a very pronounced sex difference in

pituitary weights; that the pituitary of the cockerel has greater gonad-stimulating potency than that of the pullet and that limitation of diet, unilateral castration, complete castration and hormone injection greatly modify pituitary growth and secretory activity. The experimental data from mammal and bird, when correlated with a detailed study of normal pituitary function, promises to clarify some of the discrepancies which exist at present.

Notes on the life history of *Neoechinorhynchus emydis* (Leidy), an acanthocephalan parasite of turtles. WILLIAM B. HOPP, Purdue University.—Specimens of *Graptemys geographica* (Le Sueur) from the Tippecanoe River have been found to harbor adults of *Neoechinorhynchus emydis* (Leidy), an acanthocephalan parasite reported from several species of North American turtles. Although experimental determination of the life cycle is not yet completed, juvenile forms which occur in the foot of the snail, *Campeloma sp.*, are believed to be young stages of *N. emydis*. Immature worms have been recovered from the intestine of painted turtles *Chrysemys bellii marginata* (Agassiz), which had been fed infected snails after examination of several of a lot collected from a pond proved to be negative for acanthocephala. Experimental attempts to infect snails by feeding eggs of *N. emydis* are in progress. To the writer's knowledge, a molluscan intermediate host has not been reported to occur in the life cycle of any other thorny headed worm. The present study indicates that, unlike other groups of parasites, closely related species of acanthocephala may differ greatly in the type of intermediate host utilized in the life cycle.

Notes on a giant cystocercous cercaria and its life history. PHILIP G. SEITNER, Purdue University.—Specimens of *Pleurocera acuta* Rafinesque and *Goniobasis livescens* (Menke), collected from the Eel River near North Manchester, have been found to harbor a new cystocercous cercaria which is remarkable for its size and the close similarity of its adult stage to *Proterometra macrostoma*, a species having a very different larval form. The cercariae may attain a length of over 19 mm., which may be as long as the shell of the snail host. Unlike other azygiid larvae, the tail furcae are weakly developed and not used in swimming. Movements are not vigorous but consist of flexing the tail stem near the middle, alternately left and right as a rule: thus the larva may be driven slowly forward or backward. Seldom, however, does it rise from the bottom of the dish. The cercaria is progenetic and the uterus may contain over 50 eggs, many of which are in an advanced stage of development. The usual criteria for distinguishing species of adult trematodes reveal no significant differences between the present species and *Proterometra macrostoma*, yet, because of differences in their larvae, the species must be regarded as distinct. This is in contrast to the usual observation that cercariae are more alike than are their adult stages.

Natural history of Indiana, a 16 mm. kodachrome motion picture illustrating the social behavior of animals. HOWARD H. VOGEL, JR.,

Wabash College.—This motion picture is designed to illustrate the types of social behavior shown by some of our common Indiana birds and mammals. A series of pictures of nesting mourning doves and of an experimental flock of chickens are used to indicate some of the important types of avian social behavior. Allelomimetic behavior (mutual imitation) is seen clearly in the young chicks. Epimeletic behavior (care of the young by parents) and et-epimeletic behavior (young calling to parents), fighting, and several kinds of defensive reactions are photographed in these birds.

A short scene shows unusual protective behavior by a wounded woodcock; the camera follows hunting dogs retrieving bobwhite quail.

The behavior of five Indiana mammals, the opossum, woodchuck, chipmunk, deer mouse, and rabbit, are photographed. There are also pictures of a captive great horned owl running on the ground in an attempt to escape; a large black snake, basking in the sun; and a frog, sitting among the lily pads of a pond.

A group of bettles on a fence post show social aggregation. Nearby a praying mantis shows its method of securing food.

The object of this film is twofold: first, to illustrate graphically osme of our common Indiana animals, and second, to show their various types of social behavior.

Demonstration of Urinary Gonadotropins in Normal Men, Using the Chick as a Test Animal.

K. K. LIAPTCHEFF AND W. R. BRENEMAN, Waterman Institute and Department of Zoology[1]

Extensive assays have been made of pregnancy urine and similar studies have been reported of normal or menopausal female urine, but comparable studies of male urine in normal or pathological conditions have been limited. It is the purpose of this paper to report some analyses of gonadotropic potency of normal male urine as measured by the response of the gonads in chicks.

Methods for quantitative concentration of urinary gonadotropic substances have attracted considerable attention in the past several years and particular interest has been attached to the application of these methods to the urine of normal individuals which, because it contains very small amounts of the active material, must be concentrated into small volumes of non-toxic extract in order to be suitable for assay. Although most assays have been made with pregnancy urine, some of these methods can be applied successfully in extraction of gonadotropins from normal male urine.

An alcohol precipitation method was introduced by Zondek (1928) which according to some investigators appeared to be the easiest and most nearly quantitative, but required additional purification procedure when applied to normal urine. Katzman and Doisy (1934) proposed a benzoic acid method of obtaining gonadotropic extracts from pregnancy urine. This was found to be too toxic for assay, when used in large amounts. Hellbaum, Fevold, and Hisaw (1935) introduced a tannic acid pyridine method, which is claimed to be quantitative since the purified extracts in comparable dose are as active as the original urine. Levin (1941) reported the first precipitation of gonadotropins from normal male urine by a new tannic acid method. The size of the yields, compared to those obtained by the other methods, suggested that tannic acid is a suitable and effective precipitant for the gonadotropins of normal urine. This method was claimed to yield the least toxic preparations. Evans and Gobraman (1942) described a modified alcoholic precipitation method for preparation of gonadotropic concentrates from normal male urine which is claimed to be superior to all other methods as to its non-toxicity and its quantitative concentration.

In connection with our work it is of interest to note that very little work has been done on assaying of urine gonadotropic extracts in birds. Several investigators have performed such experiments by using pregnancy urine extracts. Riddle (1931) showed failure of pregnancy urine extracts, prepared by the Zondek method, on testes of immature pigeon or

[1] Waterman Institute No. 96 and Zoology No. 350.

ring-dove as a test object for qualitative and quantitative measurement of urine gonadotropins, regardless of the dose level employed. Schockaert (1934) injected extracts from pregnancy urine, prepared by the Zondek method, to chicks, found that these extracts were inactive in these forms in regard to the endocrine and the gametogenic functions. No increase in growth of the testes or the comb was observed.

Materials and Methods

Pooled samples of urine of the male staff of the department and college men were precipitated in lots of 18-21 liters. For extraction of the gonadotropins from the urine, Fevold's method was used at first, but later it was replaced by Levin's method which was found to be easier and faster.

The gonadotropic potency of the normal male urine was determined by assaying the extract in chicks and observing its effect on chick testicular weight. The method employed was that described by Byerly and Burrows (1938) according to which the chicks were kept in shipping boxes without food or water during the 96-hour assay period. The chicks were divided into different series, each of which received different concentrations of the extract. The concentrations ran from 100-800 cc. equivalents of urine per chick. The final extract was dissolved in water of such volume that 1 cc. of the extract was equivalent to 1000 cc. of urine. All injections were made subcutaneously and each chick received six injections of .25 cc. each at intervals of 12 hours. The control chicks were injected with water. At the fifth day, the chicks were killed by breaking the neck, testes were removed, weighed, and placed immediately into Helly's modification of Zenker's fixative. The tissues were embedded, sectioned in the customary manner, and then stained with Harris hematoxylin and eosin.

The estimation of the gonadotropic potency was made in terms of "chick units" since rarely more than ten birds were used in each series, 25 per cent increase of gonad weight above the control average was considered to constitute a chick unit. In this paper only standard errors for percentage gonad weights are presented, because according to Breneman (1945), the standard errors for percent body weight do not differ significantly from those for the gonad weight. In all the experiments, only single comb White Leghorn cockerels received 12 hours after hatching were used.

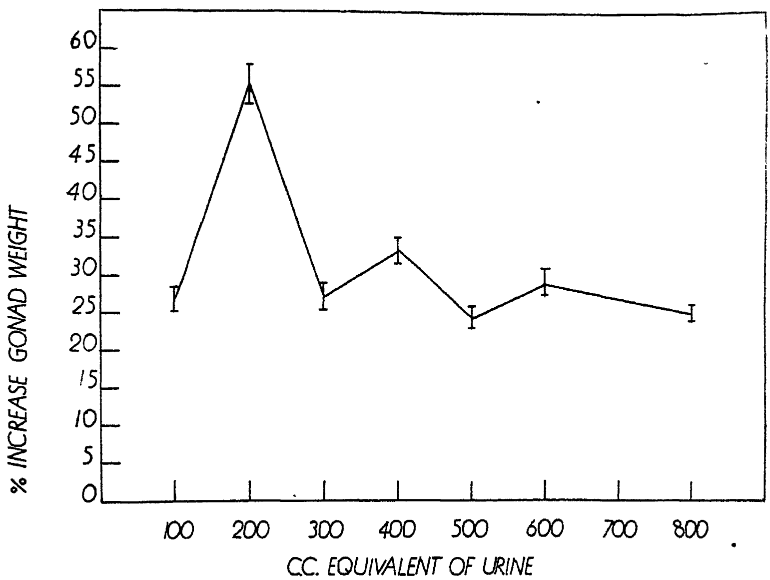
Results and Discussion

The consistent increase in gonad weights of the injected chicks over the controls, which was observed throughout the period of experimentation, indicates that there are some gonadotropic substances present in the normal male urine and that the chick gonads are very sensitive to such concentrations of gonadotropins.

Graphs I and II illustrate the results obtained with extracts prepared according to Fevold's and Levin's methods respectively for the

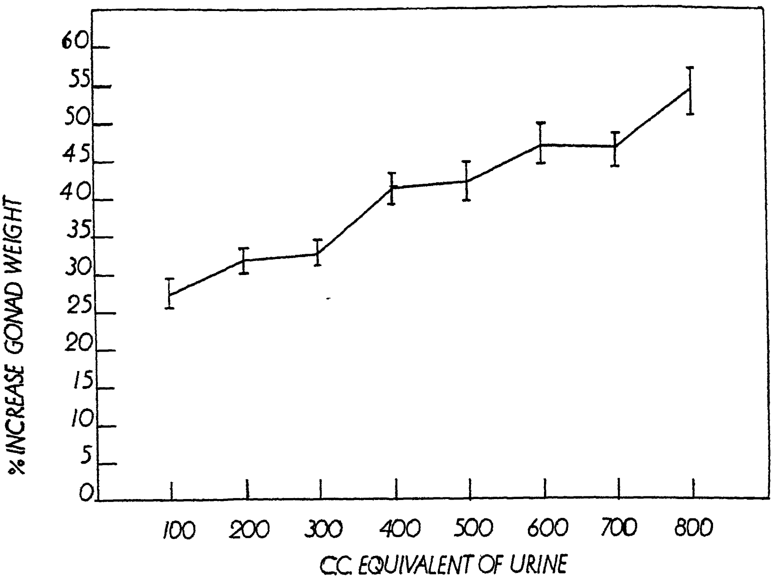
extraction of gonadotropins from pregnancy and normal male urines. An analysis of these graphs demonstrates a striking difference in the gonad weights, following injection of extracts prepared by the first method (Fevold's) when compared with those which resulted from the administration of extracts using the second method (Levin's).

The extracts prepared by the Fevold's method exceeded slightly the potency of those prepared by the Levin's method at low dosage level (note 200 cc. equivalents of urine per chick), but it was toxic when used at higher dosages than 600 cc., because most of the birds injected with such dosage began to die after the second injection. The curve representing the increase of the gonad weight of injected chicks over controls, after reaching a peak at 200 cc., abruptly fell to the level



Graph I. Gonadotropic potency of extracts prepared by the Fevold's method. Vertical lines represent standard errors. A total of 200 animals were used to determine the curve.

of the lowest dosage, and rose again in two peaks each smaller than the first one. The greatest increase of the gonad weights was obtained with extracts of 200 cc., (equal to 2.22 chick units) and the smallest with extracts of 500 cc. (equal to .93 chick units). The irregularity of this curve can probably be explained by the toxicity of the extracts which may be due to the incomplete purification of the final extract, or by the presence of some toxic or inert substances the toxicity of which could be noticed only at high dosage levels. The toxicity of the extract and the irregularity of the results obtained by this method necessitated the application of another method which could give better results.



Graph II. Gonadotropic potency of extracts prepared by the Levin's method. Vertical lines represent standard errors. A total of 500 animals were used to determine the curve.

Levin's method was found to be less toxic than Fevold's even when given in concentrations as high as 800 cc. It was also found to be simpler and required very little time for extraction. In the results obtained by extracts of this method, a correlation was shown between the increase in the gonad weight and the increase in concentration of the extract. There was a general tendency for progressive increase in a straight line with a little deviation due to the fact that results with concentrations of 300 and 700 cc. were a little below, and with concentrations of 400 cc. a little above this line. The increase in gonad weights with this extract ranged from 1.08 chick units for the lowest dosage level (100 cc.) to 2.17 chick units for the highest dosage levels (800 cc.).

Histological data failed to demonstrate any significant increase in the size of the tubules or relative increase of the interstitial tissue. There are some indications of formation of lumina and increase in the total diameter of the gonads of the injected chicks. In the control chicks, a general retrogradation of the gonads was observed which is probably due to the process of inanition used during the period of experimentation.

From the above data we may conclude that in the normal male urine the concentration of the gonadotropic substances is very low. Although it is sufficient to keep the gonads of the injected chicks from retrogradation, it is not sufficient to stimulate them.

Summary

Assays of gonadotropic substances of normal male urine were made using the 96-hour chick test. The gonadotropic potency was determined in terms of chick units, using 25 per cent increase of gonad weight over controls as a chick unit. Two different methods were used for extraction of the gonadotropins from the urine, Fevold's and Levin's, but the first extract was found to be toxic when given in high dosages.

The preparations obtained by the Levin method were less toxic than Fevold's and showed a correlation between the increase in the gonad weight and increase in the concentration of the extract. The potency of extracts prepared by the Fevold's method ranged from .93 chick units (for concentration of 500 cc.) to 2.22 chick units (for concentration of 200 cc.). For Levin's method extracts the potency ranged from 1.08 chick units (or concentrations of 100 cc.) to 2.17 chick units (for concentrations of 800 cc.).

Histological data failed to demonstrate any significant increase in size of tubules or relative increase of interstitial tissues. There was some indication of formation of lumina and increase in total diameter of the gonads of the injected chick.

These data indicate that there are some gonadotropic substances present in the normal male urine which will affect the avian testes.

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Cellular Constituents and Chemistry of the Hamster's Blood

C. L. Rose, J. R. Hannah, and K. K. Chen,
Lilly Research Laboratories

The contacts with tropical diseases which our armed forces have had during World War II have markedly increased the interest in this class of ailments. Beyond the investigations in bird and monkey malaria and the work on amebic dysentery in the monkey, very little has been done in this field, because there have been no suitable laboratory animals to act as hosts. The comparatively recent work of Adler (1) and Soong and Anderson (2) on the transmission of leishmaniasis to the hamster has made that animal very important in experimental therapy.

Considerable work has been done on the hamster, particularly in the field of infectious diseases. Although blood cell studies have been conducted (3, 4), blood chemistry has not been attempted to a great extent. Since some knowledge of these factors is essential in the use of an animal for the investigation of the effect of drugs, we found it necessary to carry out certain experiments. Our work on the response of the hamster to drugs appears elsewhere (5).

The purpose of the present study was to establish some blood chemistry standards and to investigate some of the hematological elements concerned with the physiology of the hamster. Throughout our experiments, the Syrian or Golden Hamster, *Cricetus auratus*, was used.

The report on the hematology of the hamster by Stewart, Florio, and Mugrage (3) made it unnecessary for us to do a complete blood study. We did, however, make total erythrocyte and leucocyte counts, hemoglobin determinations, and differential counts (Table I). In addition, the more common blood chemistry tests, including those for uric acid, urea, creatinine, non-protein nitrogen, calcium, inorganic phosphorus, and prothrombin, were applied (Tables II, III, IV, and V).

Our animals were obtained from a dealer and allowed to become acclimated to our air-conditioned quarters for about a week. Their food consisted of a commercial diet, "Purina Laboratory Chow," with a liberal addition of kale. All hamsters were between 2 and 5 months old.

The hamster tends to bite anyone who handles it. It is necessary, therefore, to hold it with leather gloves. In order to draw blood for cell counting, the animal is placed in a telescope-like holder. The right hind leg is allowed to protrude from a slot in the side of the holder. A needle prick through the shaved skin into a superficial vein of the exposed leg will permit a sufficient blood flow. This procedure, however, does not allow withdrawal of enough blood for chemical analysis. It is necessary, therefore, to anesthetize the hamster and make a cardiac puncture.

The total erythrocyte and leucocyte counts are the average of duplicate counts on the same group of animals. The blood was col-

Table I. Blood Counts on the Hamster

Animal Number	Sex	Weight	Hemoglobin	Erythrocytes	Leucocytes	Neutrophiles	Lymphocytes	Monocytes	Eosinophiles
		gm.	*gm. per 100 cc.*	*millions per cmm.*	*thousands per cmm.*	*per cent*	*per cent*	*per cent*	*per cent*
1	M	84	18.0	8.5	9.2	27	71	2	0
2	M	100	17.1	8.9	9.3	29	65	3	3
3	M	100	19.2	9.7	8.1	27	72	0	1
4	M	90	16.8	9.6	8.5	30	64	4	2
5	M	90	20.0	8.8	8.9	28	69	2	1
6	F	102	21.0	8.9	8.6	29	69	1	1
7	M	88	15.0	7.5	8.8	32	65	3	0
8	M	115	18.0	9.3	9.3	26	70	2	2
9	M	95	17.2	8.2	8.1	25	73	2	0
10	F	110	18.3	9.7	8.3	31	68	1	0
Mean ± Standard Error			18.06 ± 0.54	8.94 ± 0.24	8.69 ± 0.18	28.4 ± 0.7	68.6 ± 0.98	2 ± 0.37	1 ± 0.33

Table II. Representative Blood Chemistry-Organic

Animal Number	Sex	Weight	Uric Acid	Urea	Creatinine	Non-Protein Nitrogen
		gm.	*mg. per 100 cc.*	*mg. per 100 cc.*	*mg. per 100 cc.*	*mg. per 100 cc.*
11	M	109	5.00	12.18	0.93	51.6
12	F	113	4.22	11.90	1.30	46.8
13	M	100	5.64	15.40	1.00	39.7
14	M	97	4.10	20.30	0.87	44.2
15	F	95	4.50	20.65	0.94	47.6
16	F	103	5.06	19.60	0.86	44.4
17	M	96	4.14	13.65	0.91	49.8
18	M	98	4.39	14.70	0.92	48.0
19	M	92	4.05	10.71	0.90	42.1
20	M	105	4.62	13.30	0.95	47.6
Mean ± Standard Error			4.55 ± 0.14	15.34 ± 1.1	0.95 ± 0.04	46.2 ± 1.1

lected and diluted in pipettes certified by the Bureau of Standards, and the counts were made in a Spencer "bright line" counting chamber. For hemoglobin determinations, the blood (0.02 cc.) was diluted with 5 cc. of N/10 hydrochloric acid, and after allowing the mixture to stand for 30 minutes, it was placed in a Fisher Electro-Hemometer. The hemoglobin content was read directly in grams per 100 cc. of blood.

The differential leucocyte count of the hamster agreed with those of other rodents. The chief difference between these findings and those recorded for man is a reversal of the neutrophile and lymphocyte percentage values. In man, the neutrophiles are in the majority; they are the scavenger cells and phagocytize invading organisms. In the rodent, the lymphocytes are greater in number than the neutrophiles.

Hamster blood in amounts up to 2 cc. was collected by cardiac puncture for chemical studies. With the exception of the serum for calcium and inorganic phosphorus determinations, all the blood samples were oxalated immediately. The improved method of Folin (6) was utilized for blood uric acid. The values obtained from 10 animals were 4.05 to 5.62 mg. per 100 cc. of blood, with an average (arithmetic mean) of 4.55 ± 0.14 mg. per 100 cc. This is a little higher than the average range for man. Urea was calculated by the aeration method of Myers, Fine, and Lough (7). These values extended from 10.71 to 20.3 mg. per 100 cc. with an average of 15.34 ± 1.1 mg. per 100 cc. The range of blood creatinine by the method of Folin and Wu (8) was 0.87 to 1.3 mg. per 100 cc. with an average of 0.95 ± 0.04 mg. per 100 cc. Non-protein nitrogen was determined by the micro-Kjeldahl method of Wagner (9). The values for the blood of 10 hamsters ranged from 39.7 to 51.6 mg. per 100 cc. with an average of 46.2 ± 1.1 mg. per 100 cc.

Blood serum calcium studies were made on 30 animals. The amount of blood required by the Tisdall method (10) made it necessary to pool the blood from 10 hamsters for each set of determinations. The result ranged from 11.7 to 13.2 mg. per 100 cc., with an average of 12.47 ± 0.43 mg. per 100 cc. Inorganic phosphorus values, obtained by the procedure of Benedict (11), ranged from 3.85 to 5.81 mg. per 100 cc. with an average of 4.33 ± 0.17 mg. per 100 cc.

Table III. Representative Blood Chemistry-Inorganic

Animal Number	Sex	Weight	Calcium
		gm.	*mg. per 100 cc.*
21	M	114	
22	F	112	
23	F	103	
24	M	95	
25	M	100	11.7
26	M	97	
27	M	94	
28	M	92	
29	F	108	
30	M	103	
31	M	87	
32	M	91	
33	F	100	
34	M	84	
35	F	96	13.2
36	M	92	
37	M	102	
38	M	113	
39	M	94	
40	M	89	
41	M	95	
42	M	98	
43	M	101	
44	F	88	
45	F	105	12.5
46	M	92	
47	M	94	
48	M	111	
49	F	90	
50	M	97	
Mean ± Standard Error			12.47 ± 0.43

Table IV. Representative Blood Chemistry-Inorganic (Continued)

Animal Number	Sex	Weight	Phosphorus
		gm.	*mg. per 100 cc.*
51	F	96	4.10
52	F	102	5.00
53	M	115	3.95
54	M	110	4.15
55	M	117	4.60
56	M	99	5.51
57	M	112	3.95
58	M	111	4.20
59	M	108	4.00
60	M	106	3.85
Mean ± Standard Error			4.33 ± 0.17

The prothrombin time of the hamster blood plasma was recorded in seconds by a modified method of Campbell, Smith, Roberts, and Link (12), in which 'Hemagulen' (Brain Thromboplastic Suspension, Lilly) was used in place of dried rabbit brain suspension. The range for whole plasma was 13 to 15 seconds, with an average of 14 ± 0.16 seconds; and for 12.5 percent plasma (diluted with physiological saline), 20 to 30 seconds with an average of 25.45 ± 0.9 seconds.

Table V. Representative Blood Chemistry-Coagulation

Animal Number	Sex	Weight	Prothrombin Time Whole Plasma	Prothrombin Time 12.5% Plasma
		gm.	*seconds*	*seconds*
61	M	119	13.0	25.5
62	M	104	14.0	29.5
63	M	113	15.0	27.0
64	F	99	14.0	30.0
65	M	105	13.0	20.0
66	M	90	13.5	20.0
67	F	106	14.0	27.0
68	M	117	14.5	21.0
69	M	113	14.0	24.9
70	M	100	15.0	30.0
Mean ± Standard Error			14 ± 0.16	25.45 ± 0.90

Summary

In order to establish a firm basis for pharmacological experimentation on the Syrian hamster, blood cell counts and blood chemical analyses have been carried out. With the exception of creatinine, all values approached or exceeded the upper limits of the standards usually given for man.

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Notes on the Odonata of the Tippecanoe River State Park, Pulaski County, Indiana[1]

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The general dragonfly fauna of Indiana has been thoroughly investigated by several authors, notably E. B. Williamson and B. E. Montgomery. However, nearly complete faunal lists for limited localities and habitats, representing specimens collected over a greater part of the season, are lacking for many areas. Published records of Odonata from Pulaski County (Montgomery 1937, 1941) list only 13 species, indicating that extensive collections from that region are not recorded in the literature. Accordingly, the author, while working with the Lake and Stream Survey of the Indiana Department of Conservation in the Tippecanoe River State Park during the summers of 1943, 1944 and 1945, collected and made observations on the odonate fauna of that locality. Specimens of 48 additional species were collected bringing the total for Pulaski County to 61.

The Tippecanoe River where it flows through the State Park averages, in times of normal water, 100 feet wide and three feet deep, although occasional "holes" at sharp bends may reach depths of nine or ten feet. Since its principal sources are lakes, the river has a relatively constant level and the water is generally quite transparent. Unusually heavy and widespread rainfalls were observed to bring about rises of as much as five feet with a corresponding considerable increase in turbidity. The fall of the river at this point is from 12 to 16 inches per mile and the current speed in midstream about two feet per second. Much of the river bottom is composed of shifting sand, but many of the shallower, swifter sections have gravel and boulder-covered bottoms. In shallow water, on favorable bottom, dense stands of Vallisneria and various species of Potamogeton develop. The river has evolved a series of broad meanders in this part of its course which has resulted in the formation of numerous quiet backwaters where heavy siltation occurs during periods of high water. The piles of drift that have accumulated about the many trees that have fallen into the stream form an important environmental factor. In addition, the matted masses of roots that hang into the water from the steeper banks offer situations suitable for many climbing aquatic invertebrates.

In the general habitat of the river valley, must be included those abandoned river channels containing water that have more or less lost connection with the river itself. During floods these are, of course, continuous with the river, but for a greater part of the summer they are completely isolated from the river and support independent fauna

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and flora. One such lagoon or bayou is to be found at Group Camp 1. Locally known as the Hoch Bayou, this body of water is a typical oxbow some 1300 feet long and 75 feet wide with a maximum depth of about five feet. Being well shaded in its shallower portions it supports only small stands of Nuphar and Nymphaea, but during favorable seasons luxuriant growths of Elodea and Cabomba develop. Unless removed by occasional high water, blankets of floating filamentous algae and Lemna form a dense surface mat.

Certain species of Odonata may be pointed out at being characteristic of these two environments. Among the zygopterans the following species might be listed as being typical of the river proper: *Calopteryx maculata, Hetaerina americana, Argia apicalis, A. sedula, A. moesta, A. tibialis,* and *Enallagma exsulans.* Of the anisopterans, the gomphines dominate the river. Those most commonly seen included: *Progomphus obscurus, Hagenius brevistylus, Gomphus lineatifrons, G. fraternus, G. quadricolor, G. vastus, Stylurus amincola, S. spiniceps,* and *Dromogomphus spinosus.* Three aeschinines were of frequent occurrence on the river: *Boyeria vinosa, Basiaeschna janata,* and *Nasiaeschna pentacantha. Macromia illinoiensis* was the only libellulid commonly observed on the open river, but other species, among them *Holotania luctuosa* and *Neotetrum pulchellum,* were always to be found about quiet backwaters. *Sympetrum rubicundulum* was seen abundantly in woods and fields adjacent to the river; other libellulines occurred similarly, but not in great numbers.

The Hoch Bayou at Group Camp 1 supported a typical pond fauna including: *Enallagma geminatum, E. signatum, Ischnura posita, I. verticalis, Anax junius, Tetragoneuria cynosura, Holotania luctuosa, Neotetrum pulchellum, Plathemis lydia, Perithemis tenera, Erythemis simplicicollis,* and *Pachhydiplax longipennis.*

The author is greatly indebted to Dr. B. E. Montgomery of Purdue University since he identified or verified some specimens of each species recorded. Mr. Paul Thompson who worked with the author on the Lake and Stream Survey in 1945 collected many of the specimens listed below, three of which were new to the locality, having never been taken by the author. The periods over which collections and observations were made extended from July 25 to August 18, 1943; from April 26 to August 12, 1944; and from May 7 to August 26, 1945. Collecting was done along the river in the vicinity of Group Camp 1 and for about two miles downstream in all three summers, also along about a half mile of river just north of the Shelter House at the Park Picnic Area in 1945. Collections were made about the Hoch Bayou in all three summers and about some of the bayous in the vicinity of the Shelter House in 1945. A total of 691 specimens referable to 59 species are listed. Most of these have been retained by the author; however, some are now in the collection of Dr. B. E. Montgomery, while others of the commoner species which were damaged or lacking in data have been discarded. Records of the discarded material have been included in the list in order to give a more complete picture of seasonal distribution.

Annotated List of Species

1. *Calopteryx aequabile* Say. 1♂, vii.4.44 (sight record).

The single specimen of this species was seen at a weedy riffle on the river. Identification was positive since the specimen was nearly taken by hand.

2. *C. maculata* (Beauvois). 1♀, vii.2.45; 1♂, vii.27.43; 2♂ 3♀, vii.28.43; 1♂, viii.2.43; 1♀, viii.12.43.

First observed in the middle of June, this species was quite abundant by early July and remained so until observations ceased in late August. Exuviae were found on trees as high as six feet above the river and an equal distance back from the bank. Adults were most frequently observed about grass or bushes along the water's edge. Oviposition occurred on floating masses of twigs and stems.

3. *Hetaerina americana* (Fabricius). 1♂ (teneral), vi.27.45; 1♂ (teneral) 2♀, vi. 28.45; 4♂ (3 teneral) 2♀, vii.2.45; 1♂ (teneral) 1♀, vii.3.45; 4♂ 4♀, vii.5.44; 1♂ 3♀, vii.7.44; 1♀, vii.11.45; 1♂, vii.17.45; 1♂ (teneral) 1♀, vii.19.45; 3♂ 1♀, vii.27.43; 1♂ (teneral) 3♀, vii.28.43; 1♂, vii.28.44; 1♂ (teneral) 1♀, vii.29.43; 1♂ 1♀, vii.30.43; 1♀, vii.31.43; 1♂ 1♀, viii.1.43; 2♂ (1 teneral) 2♀, viii.10.43.

A common species, first observed in numbers in late June. The adults of both sexes congregate about willows that hang over into fast water, about brush that emerges from fast water, and in grass at the very edge of the water.

4. *Lestes disjunctus* Selys. 1♂ 1♀, vii.28.44.

5. *L. forcipatus* Rambur. 2♀, vii.28.43.

6. *L. inaequalis* Walsh. 1♂ 1♀, vii.11.45; 1♀, vii.28.43.

7. *L. rectangularis* Say. 1♂, vii.2.45; 1♂ 1♀, vii.8.45; 7♂, vii.10.45; 2♂, 5♀, vii.11.45; 1♂, vii.13.44; 1♀, vii.19.45; 1♂, vii.20.45; 1♂, vii.28.45.

8. *L. dryas* Kirby. 1♀, vii.11.45.

9. *L. unguiculatus* Hagen. 1♀, vii.7.44; 1♀, vii.19.45; 8♂ 6♀, vii.27.43; 6♂, viii.23.45.

The six species of *Lestes* recorded above were all taken in grass or bushes within a few hundred feet of the river or one of the bayous. *L. unguiculatus* and *L. rectangularis* were the only species that were at all common. The latter seemed to prefer the shade of wooded areas along the river while *L. unguiculatus* was more often seen in clearings.

10. *Argia apicalis* (Say). 1♀, vii.25.43; 3♂, vii.26.45; 6♂ 2♀, vii. 28.44; 2♂, 4♀, vii.29.43; 1♀, vii.30.43; 1♂, viii.10.43; 3♂ 1♀, viii.26.45.

The habits of this species are similar to those of the much more abundant *A. tibialis*. It did not appear commonly, until late July and maintained only a moderate abundance until observations ceased in late August.

11. *A. moesta* (Hagen). 1♂, vii.26.45; 8♂, vii.28 to viii.5.44; 1♀, vii.29.43; 2♂, undated 1944.

This *Argia* differs in habits from the other common species recorded. It was most often encountered flying along a few inches above the water in midstream and showed little tendency to be gregarious. While of moderate abundance, it was relatively difficult to capture.

12. *A. sedula* (Hagen). 1♀ (teneral), vii.20.45; 2♂, vii.26.43; 2♂, vii.27.43; 3♂ 7♀, vii.27 to viii.3.44; 1♀, vii.29.43; 1♂, viii.12.43; 2♂ 1♀, viii.26.45.

The habits of *A. sedula* are similar to those of *A. apicalis*. It was found over the same seasonal range as that species but somewhat less commonly.

13. *A. tibialis* (Rambur). 4♂ (3 teneral), vi.20.45; 1♂ 1♀, vi.23.45; 4♂ 3♀, vi.26.45; 1♂ 1♀, vi.28.45; 3♀, vii.2.45; 3♂ 4♀, vii.3.45; 5♂ 1♀, vii.6.44; 3♂ 1♀, vii.8.45; 1♂ 2♀, vii.11.45; 2♂ 2♀, vii.19.45; 2♂, vii.27.43; 9♂ 11♀, vii.27 to viii.3.44; 2♂ 2♀, vii.28.43; 1♂, viii.2.43; 1♂, viii.10.43; 1♂, viii.26.45.

A. tibialis was the first species of this genus to emerge, appearing shortly after mid-June and becoming exceedingly abundant by the first week in July. Large groups of mating and ovipositing pairs were observed throughout July and into August. These aggregations were always found where quantities of floating debris had been trapped within drifts, usually in moderate current.

14. *A. violacea* (Hagen). 1♂, vii.31.43.

Although watched for rather carefully, this species was taken only once and must be considered rare for this locality.

15. *Enallagma antennatum* (Say). 1♀, vii.10.45.

The single specimen recorded was collected at the Picnic Area by Paul Thompson.

16. *E. exsulans* (Hagen). 1♂, 1♀, vi.23.45; 1♂, vi.27.45; 1♂ (teneral), vii.1.45; 2♂ 1♀, vii.2.45; 1♂, vii.7.44; 5♂ 1♀, vii.11.45; 1♂, vii.11.44; 2♂ 2♀, vii.13.44; 3♀, vii.19.45; 1♂, vii.28.43; 5♂ 3♀, vii.28 to viii.5.44; 1♂, viii.1.43.

Quite abundant both on the river and the Hoch Bayou throughout a rather long flying season from late June through August

17. *E. geminatum* Kellicott. 3♂ 1♀, vii.28.43.

The specimens recorded were taken on the Hoch Bayou where this species was not common.

18. *E. hageni* (Walsh). 1♂, vii.10.45; 1♂, undated 1945.

One specimen of this species was collected along one of the bayous near the Shelter House by Paul Thompson; the undated one by the author at the Hoch Bayou.

19. *E. signatum* (Hagen). 2♂ 2♀, vii.28.44; 1♀, viii.12.43.

A fairly common species on the Hoch Bayou and occasionally seen over quiet backwaters of the river.

20. *Nehalennia irene* Hagen. 1♀, vii.11.45.

Apparently quite scare. A single specimen collected in 1944 has been lost. The one recorded above was caught in grass along the river.

21. *Chromagrion conditum* (Hagen). 2♂, v.28.44.

Both of the above specimens were collected by I. Owen Foster Jr. along one of the ditches which flank the road leading to Group Camp 1. Although probably not a part of the fauna of the river or its flood plain, this species is here included because of the scarcity of Indiana records of it.

22. *Ischnura posita* (Hagen). 2♂, v.26.44; 1♂ 1♀ (1♀ teneral), v.26.45; 2♂, .27.45; 1♂ 1♀, vii.28.44; 1♂, vii.29.43.

A rather uncommon species, collected in grass along the river and about the Hoch Bayou.

23. *I. verticalis* (Say). 1♀, v.24.44; 3♂ 3♀, v.25.44; 1♀, v.26.44; 1♂ (teneral), v.26.45; 1♂ 1♀ (both teneral), v.27.45; 1♀, vii.11.44; 1♂, vii.11.45; 1♂ 1♀, vii.26.43; 1♂ 1♀ (♀ teneral), vii.28.43; 4♂ 3♀, vii.28.44; 3♂ 2♀, vii.29.43.

A very abundant species along the river banks and around all bayous visited.

24. *Progomphus obscurus* (Rambur). 2♀ (tenerals), vii.1.45; 2♀, vii.2.45; 1♂ vii.3.45; 1♂ 1♀, vii.5.44; 1♀, vii.18.44; 1♂, vii.18.45; 1♂, vii.20.44.

This midsummer gomphine was moderately common It was often observed cruising up and down the river a few inches above the water or resting on sand bars.

25. *Hagenius brevistylus* Selys. 1♂ (emerging) 1♀, vi.21.45; 1♀, vi.23.45; 1♂, vi.27.45; 1♂, vii.1.45; 1♀, vii.3.45; 1♀, vii.6.44; 1♀, vii.8.45; 1♂, vii.11.44; 1♀, vii.11.45; 1♂, vii.18.45; 1♂, vii.27.43; 1♂, viii.2.43; 1♂, viii.6.43; 1♂, viii.9.43; 2♂, viii.10.43; 1♂, viii.12.43.

Hagenius was one of the few gomphines which could be seen almost every day all summer long. Despite its size and flying ability it was not very difficult to take, partly because of its fearlessness and partly because of its habit of flying a "beat" with definite perches along it. A female of this species was observed ovipositing late in the afternoon of July 14, 1945. She faced a bank of the stream which rose abruptly about four feet from the water. The bank was hung with a mass of roots and rootlets of a nearby silver maple. She would hover for an instant a few feet from the bank and about a foot above the water, then flying toward the bank and dropping, she would dip her abdomen at the water's edge, rise a few feet and return to her original position

without turning around. This action was repeated several dozen times without interruption.

26. *Ophiogomphus rupinsulensis* (Walsh). 1♀ (emerging), vi.1.45; 1♂ (teneral), vi.9.45.

The emerging female was taken on a root a few inches above the water about nine a. m. The teneral male was floating down midstream, helpless. Besides these recorded specimens, one adult was seen in mid-June of 1945. A rather rare species for the locality.

27. *Erpetogomphus designatus* Hagen. 1♀ (emerging), vii.11.45.

The single specimen taken was found by Paul Thompson at his camp near the Shelter House. The mature nymph was ascending some roots along the river bank. Only one additional specimen was seen in late July hence this too must be considered a rare species.

28. *Gomphus lineatifrons* Calvert. 1♂, vi.4.44; 1♂, vi.19.45; 1♀, vi.21.45; 3♂ 1♀, vii.1.45; 3♀, vii.2.45; 1♂ 2♀, vii.4.45; 1♂ 1♀, vii.5.45; 1♀, vii.6.44; 1♂, undated 1944.

A very common member of the genus *Gomphus* from early June to mid-July, seen occasionally over the Hoch Bayou. A female captured July 2, 1945, was in the act of eating a specimen of *Progomphus obscurus*.

29. *G. fraternus* (Say). 2♂ (1 teneral) 1♀ (teneral), v. 28.44; 1♂, vi.1.44; 1♂ (teneral), vi.10.45; 1♂, vi.12.45; 2♀ (tenerals), vi.14.45; 1♂, (teneral), vi.15.45; 2♂ (teneral), vi.18.45; 1♀, vi.20.44; 1♀, vi.21.45; 1♂, vi.22.44; 1♂, vi.22.45; 1♂ 1♀, vii.1.45; 1♀, vii.3.45; 1♂, vii.8.45; 1♂, vii.25.45; 1♀, vii.30.44; 1♂, undated 1944.

The commonest gomphine observed, with a flight season extending from late May through late July. A peak of abundance was reached in the first week of July when many copulating pairs were seen in a meadow by the river.

30. *G. lividus* Selys. 1♂, v.24.44; 1♂ (teneral), v.27.45; 2♂ 1♀, v.28.44.

A rather scarce species.

31. *G. quadricolor* Walsh. 3♂ (tenerals), v.24.44; 1♀, v.28.44; 1♂, vi.244; 1♂ (teneral), vi.2.45; 1♀, vi.3.44; 2♂, 1♀, vi.4.44; 1♂ 3♀ (all tenerals), vi.6.45; 1♂, vi.20.44; 2♂ 1♀, vi.21.44; 1♀, 22.44; 1♀, vi.28.45; 1♀, vii.1.45; 1♀, vii.3.45; 1♀, vii.4.45; 1♀, vii.6.45.

Very common in late May and early June.

32. *G. vastus* Walsh. 1♀, vii.1.45; 1♀, vii.2.45; 1♀, vii.3.45; 1♀, vii.4.45; 1♀, vii.6.44; 1♀ vii.8.45.

Not a very common species with a rather limited seasonal range.

33. *G. ventricosus* Walsh. 1♀ (teneral), vi.6.45; 1♀ (teneral), vi. 8.45; 1♀, vi.27.45; 1♀, vii.13.45.

A rather scarce species, but apparently one with a rather long seasonal range.

34. *Stylurus amnicola* (Walsh). 1♂, vi.27.45; 1♂ (teneral), vi.28.45; 1♂, vi.30.45; 3♂ 3♀, vii.2.45; 1♂ 2♀, vii.3.45; 3♀ (tenerals), vii.5.45; 1♀, vii.6.45; 1♂ 1♀, vii.9.45; 2♂, vii.10.45; 1♂, vii.13.45.

Although first recorded in the state from Knox County in 1924 (Montgomery 1925) and taken in but two additional localities (Tippecanoecanoe County, Montgomery 1937 and Warren County, Montgomery 1941) since that time, this species was one of the most abundant gomphines encountered on the river.

35. *S. spiniceps* (Walsh). 1♂ (emerging) 2♀ (1 emerging, 1 teneral), vii.23.45; 1♂ (teneral), vii.25.45; 1♀ (teneral), vii.no date.45; 1♂, viii.no date.44; 1♀, viii.27.45.

This gomphine was the last to appear in the summer and was never very common.

36. *Dromogomphus spinosus* Selys. 1♂ 1♀ (both teneral), vi.21.45; 1♂ (teneral), vi.23.45; 1♂ (teneral), vi.27.45; 1♂ (teneral), vi.28.45; 2♂ (1 teneral), vii.3.45; 1♀, vii.5.45; 1♂, vii.6.44; 1♂, vii.7.44; 1♂, vii.9.44; 1♂, vii.20.44; 1♀, vii.22.45; 1♀ (teneral), vii.27.45; 3♂, viii.10.43; 2♂, viii.12.43; 1♀, viii.23.45.

A very common species first observed in late June and still flying when observations ended in late August.

37. *Boyeria vinosa* (Say). 1♂, vii.19.45; 1♂, vii.29.44; 1♀, viii.16.45; sight record, ix.20.45.

This species is much more common than the above records show. It emerges in late July and flies at least until late September. All individuals observed were flying "beats" a foot or two above the water along the edges of the river, usually in late afternoon or evening.

38. *Basiaeschna janata* (Say). 1♀ (teneral), v.25.44; 1♂ (teneral), v.26.44; 1♀, v.28.44; 1♂, vi.1.45; 2♂, vi.2.44; 1♂ (teneral), vi.7.45; 1♂, vi.10.45; 1♂, vi.29.45.

A fairly common species over the river and the Hoch Bayou, but seldom seen after July 1.

39. *Anax junius* (Drury). 1♀, vi.19.45; 1♀, vi.20.45; sight record, ix.20.45.

Although seen frequently over the Hoch Bayou and fields adjacent to the river, this species was taken only once on the river proper. The female collected June 20, 1945, was taken on a grapevine a few inches above swift water.

40. *Nasiaeschna pentacantha* (Rambur). 2♂ 1♀, vi.2.44; 1♂ 3♀, vi.3.44; 1♂, vi.19.45; 1♂ 2♀, vi.27.45; 1♀, vii.2.45; 1♀, vii.26.45.

This species followed *Basiaeschna* in emergence by a week or ten days and like that species was seen hawking over both the river and bayou. It was fairly common in both habitats in mid-June and a few were seen as late as mid-August. The female captured July 2, 1945, was eating a specimen of *Gomphus vastus*.

41. *Macromia illinoiensis* Walsh. 1♀ (emerging), vi.10.45; 1♀ (emerging), vi.14.45; 1♂ 1♀ (both teneral), vi.21.45; 1♀, vi.29.45; 1♀ (emerging), vii.2.45; 1♀ (teneral), vii.5.44; 1♀, viii.1.45; 1♂, viii.14.45; 1♀, viii.17.45.

Common from mid-June through August but difficult to capture. Females were frequently seen cruising up and down the river a foot or so above the middle of the stream occasionally dipping their abdomens. Individuals of both sexes often patrolled the paths about the camp, more than a quarter of a mile from the river.

42. *Epicordulia princeps* (Hagen). 1♂, vii.3.45.

A few specimens were seen about the parking lot at the Shelter House by Paul Thompson, but only one was taken. They evidently had come there to hunt from a nearby bayou.

43. *Tetragoneuria c. cynosura* (Say). 1♂ (teneral), v.24.44; 1♂, v.26.44; 4♂ (1 teneral) 1♀, v.28.44.

This libelluline was very common over the Hoch Bayou early in the season, but after mid-June its place in the fauna seemed largely taken by *Pachydiplax longipennis.*

44. *T. c. simulans* Muttkowski. 1♀, v.28.44; 1♂, vi.1.44.

This form was taken flying with typical *T. c. cynosura* over the Hoch Bayou.

45. *Holotania luctuosa* (Burmeister). 1♂ (teneral), vii.2.45; 1♂, vii.5.44; 2♀ (both teneral), vii.7.45; 4♂, vii.27.43; 1♀, viii.1.43; 2♀, viii.2.43.

Very abundant over the bayous and quieter parts of the river.

46. *H. vibrans* (Fabricius). 1♀, viii.9.43.

The single specimen was taken over a meadow adjacent to the river.

47. *Eolibellula semifasciata* (Burmeister). 1♂, vii.30.43.

Taken in the same habitat as the preceeding species.

48. *Neotetrum pulchellum* (Drury). 2♀, v.25.44; 1♂, v.28.44; 1♂ 1♀, vi.3.44; 1♂, vii.4.45; 1♂, vii.5.45; 1♂ 1♀, vii.18.45; 1♂, vii.30.43.

Very common over the bayous and quiet parts of the river.

49. *Plathemis lydia* (Drury). 1♀, v.24.44; 1♂, v.28.44; 1♂ 1♂, vi.1.44; 1♂, vi.22.45; 1♂, vi.27.5; 1♀, vii.2.45; 1♀, vii.5.45; 1♂, vii.11.44; 1♀, viii.1.43; 1♂ ♀, viii.2.43; 1♂ 1♀, viii.5.43.

A very common species on meadows along the river, about the bayous and still parts of the river. Often seen about the paths and buildings at the camp.

50. *Perithemis tenera* (Say). 1♂, vii.28.43; 1♂, vii.28.44; 1♀, vii.29.44; 3♂, vii.31.43.

Not very common over the Hoch Bayou and only occasional over backwaters along the river.

51. *Erythemis simplicicollis* (Say). 1♂, vii.6.44; 1♂, vii.26.43; 1♀, vii.29.44; 1♀, viii.1.43; 1♀, viii.10.43.

Moderately common, particularly over grassy clearings along the river.

52. *Sympetrum ambiguum* (Rambur). 1♀ (teneral), vii.4.45; 1♀, vii.8.45; 1♂, viii.23.45 (W. side).

Rather rare but widespread. The July 4 specimen was taken at the Picnic Area, the July 8 specimen at Group Camp 1, and the August 23 specimen in a swampy area in the northwest corner of the park.

53. *S. obtrusum* (Hagen). 1♂, vi.30.45; 1♂, vii.2.45; 1♀, vii.9.45; 1♀, vii.13.45; 1♂, vii.29.44; 1♀, viii.22.45; 1♂, viii.23.45 (W. side).

Not common, sharing the same habits as *S. rubicundulum*.

54. *S. rubicundulum* (Say). 1♀, vi.21.44; 3♂ 9♀ (tenerals), vi.30.45; 2♂ 5♀ (3 teneral), vii.1.45; 2♂ (teneral) 1♀ (teneral), vii. 2.45; 2♀, vii.4.45; 1♂ 4♀, vii.5.45; 3♂ 2♀, vii.6.44; 3♀, vii.6.45; 2♂ (tenerals) 3♀ (2 tenerals), vii.8.45; 1♂ 2♀ (1 teneral), vii.10.45; 1♂ 4♀ (1 teneral), vii.11.45; 1♂ 5♀, vii.13.45; 2♂ 1♀, vii.19.45; 1♂, vii.26.44; 1♀, vii.28.43; 1♂, vii.28.44; 1♀, vii.29.43; 1♂, vii.29.44; 1♀, vii.30.44; 1♀, viii.no date.44; 9♂ 4♀, viii.23.45 (W. side).

This species was abundant everywhere, often quite far from water; it was most often taken, however, on bushes about the edges of fields and over grassy areas.

In the series collected, two specimens (1♀, vii.8.45 and 1♀, vii.30.44) very definitely fitted the description of the form *assimulatum*. Ten other specimens, six males and four females, showed more or less tendency toward *assimulatum* in their wing coloration.

55. *S. vicinum* (Hagen). 1♀, vii.10.45; 2♀, vii.28.44.

Rare, at least during the periods when collections were made.

56. *Pachydiplax longipennis* (Burmeister). 3♂ 1♀, vi.1.45; 1♂. vi.20.44; 1♂, vi.21.44; 1♀, vi.22.44; 1♀, vii.2.45; 1♀, vii.8.45; 2♀, vii. 26.43; 1♂ (teneral) 2♀, viii.2.43; 2♂, viii.10.43.

Very abundant over the Hoch Bayou from the first of June through August, but only occasional over the quieter parts of the river.

57. *Leucorrhinia intacta* (Hagen). 1♂, v.24.44; 1♂, v.25.44; 1♀. v.26.44; 1♂, v.28.44; 1♂, vi.3.44; 1♀, vi.4.44; 1♀, vii.10.45.

Only of moderate abundance along the quieter waters of the river. About dusk early in the season five or six individuals of this species would gather about the author as he stood by the river. They would dance about a few feet away, but every few moments one would dash up, snatch a mosquito from the flock attracted to the writer, and then return to hover with his fellows.

58. *Tramea carolina* (Linnaeus). 1♂, vii.11.45.

This was the only specimen seen, it was hovering above grass at the edge of the river.

59. *T. lacerata* Hagen. 1♂, viii.24.45.

Captured flying along a path in Group Camp 1. It was the only specimen seen.

Of the 13 species recorded from the county by Montgomery, two, *Enallagma civile* and *Sympetrum corruptum,* were not taken by the author.

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Phylogenetic Interpretations in the Teaching of Comparative Vertebrate Anatomy

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It has seemed to me that for far too long a time obsolete views pertaining to the phylogeny of vertebrates and their organ-systems have been perpetuated in courses in Comparative Vertebrate Anatomy. The interpretations presented in the usual textbook and laboratory manual are, to a considerable extent, a reflection of those "great generalizations" which have come down to us from the late nineteenth and early twentieth centuries, generalizations which are strongly colored by the principle of recapitulation. Surely it is time to take cognizance of modern evidence and revise our teaching accordingly. This is especially true for the laboratory program wherein the customary series of animal forms, viz. shark, urodele, and mammal, tells an utterly distorted phylogenetic tale. It is the purpose of this discussion to suggest certain important re-interpretations, with an eye particularly to a revision of the laboratory program.

The Ancestry of the Vertebrates

Historically, almost every invertebrate phylum other than the Mollusca has been proposed as a possible progenitor of the chordate line. Except for one group, however, all have been eliminated for one reason or another. That one group favored by present-day opinion is the Echinodermata. Certain similarities in the early development of echinoderms and chordates have long been recognized and it is in terms of embryogeny that their phyletic relationship is customarily established. Long recognized, also, has been the morphological likeness between certain echinoderm larvae and the Tornaria of the balanoglossids. Accordingly, the Echinodermata and Chordata have been derived from a common stem, the hypothetical Dipleurula. From this stock the echinoderms are believed to have evolved as one major stem and the chordates as another. There is a tendency now-a-days, however, to assign the Hemichordata to a separate branch and thus set them off the main line of urochodate-cephalochordate-vertebrate ("Chordonia") evolution (Gislen, 1930). In such a phyletic scheme, it may be questioned whether the hemichordates are to be considered chordates at all, but represent, instead, a phylum of their own.

All such schemes, of course, place strong reliance on embryological data and require the assumption of the general validity of the recapitulation principle. But other facts are available for support of the thesis of origin of the chordates from echinoderm stock. Certain Paleozoic carpioid echinoderms (Abel, 1920) exhibit modifications in

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the direction of bilateral symmetry and some even approach the general patterns of the Ostracoderms, forms whose basic position in the phylogeny of vertebrates is now generally granted. So perhaps the postulation of an ancestral, bilateral Dipleurula is unnecessary; it is not impossible that some radially symmetrical echinoderm or echinoderm-like stock may have inaugurated a new developmental trend toward "chordateness."

More recently, biochemical (Needham et al, 1932) and serological (Wilhelmi, 1942) tests have indicated that extant echinoderms are more closely related to chordates than they are to any other invertebrates.

With the hemichordates set off on a side branch, they cannot be considered as having played a role in the direct ancestry of the vertebrates. Nor are tunicates and Amphioxus, despite their position on the stem "Chordonia," much more illuminating. The tunicates have never been accepted as direct intermediaries between vertebrates and their progenitors. Their specializations are too many and too profound. And Amphioxus, traditionally interpreted as an ancestral type (Willey, 1894), is now-a-days recognized as greatly specialized in some respects and degenerate rather than primitive in others. Leach (1944) is perfectly right when he suggests that teachers of comparative anatomy and vertebrate phylogeny should abandon it as an introductory type form. The likelihood is that Amphioxus, instead of being ancestral to the vertebrates, is a degenerate and greatly specialized derivative of the oldest known vertebrates, the Paleozoic Ostracoderms (Gregory, 1936). The same may be true of the tunicates.

As the situation stands, then, it is generally agreed that the vertebrates trace their origin to an echinoderm-chordate stem. But a great gap exists between the echinoderms and the vertebrates. That gap is filled in neither by extant non-vertebrate chordates nor by fossil forms.* While in the Cambrian deposits the major invertebrate phyla, including echinoderms, are represented, no vertebrates have been found. Yet in the immediately following Ordovocian deposits the relatively well organized first vertebrates, the Ostracoderms, are present. The vertebrates, that is, made an abrupt appearance on the evolutionary scene and for the time being their immediate ancestors remain unknown.

Ammocoetes as an Ancestral Type

As indicated above, Amphioxus is more likely a derivative rather than ancestor of the first vertebrates. On taxonomic grounds alone, then, it should be eliminated as an ancestral type. But since laboratory forms can merely simulate rather than duplicate phylogenetic stages anyhow, this would not be serious provided Amphioxus fulfilled the qualifications of illustrating general chordate anatomy. It has been

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* Since this manuscript went to press, there has appeared an important paper (White, E. I., 1946. Geol. Mag., vol. 82, no. 2) describing a new Silurian chordate, Jaymoytius kerwoodi, a fish-like animal without scales and devoid of bone and cartilage. It is believed by its discoverer to represent the kind of organism from which the fishes, Ostracoderms and perhaps even the Cephalochordata could have been derived.

my experience, however, that as an introductory laboratory form its liabilities are greater than its assets. Careful and time-consuming explanation of its specializations must be made if students are to be prevented from drawing erroneous conclusions. Peculiar to Amphioxus and devoid of archetypal significance are: the atrium and reduced coelom, the position and character of the gonads, the elaborately developed pharynx with its great number of gill slits and bars, the degenerate brain, and finally the annelid-like excretory organs. Concerning these last, Goodrich (1902, 1934) has clearly shown they are protonephridia with solenocytes such as occur in certain polychaete annelids. These tubules have nothing in common with vertebrate nephrons and the time has long since come when writers of textbooks should cease referring to them as pronephric tubules.

What form shall replace Amphioxus as an introductory type for laboratory study? The answer is Ammocoetes, the larva of the fresh-water lamprey.

It is now fairly generally agreed that of all the known vertebrates, extant and extinct, the oldest and most primitive are the Ostracoderms of Silurian and Devonian times. Of all living vertebrates, the nearest relatives of the Ostracoderms are the Cyclostomata. Modern adult cyclostomes exhibit many degenerative specializations which, as with Amphioxus, make them undesirable as generalized types. But their larval stage lacks most of these specializations and shows a remarkable similarity to the cephalaspid Ostracoderms (Stensio, 1927). As an introductory laboratory form, then, Ammocoetes serves two purposes: (1) it simulates the structure of the Ostracoderms, the basic stock from which, so far as we know, all the other vertebrates have been derived; (2) by way of it the student is introduced to basic structures and relations common to all vertebrates, without the distractions imposed by irrelevant specialization.

The literature on Ammocoetes is abundant and material for laboratory study easily available. Small specimens prepared as transparent wholemounts are especially desirable, supplemented by selected cross-sections and large specimens for gross dissection.

It is in conjunction with the evolutionary history of the various organ-systems of vertebrates that the recapitulation principle has exerted its greatest influence on teaching practices. For some curious reason obsolete interpretations have been maintained in the face of conflicting evidence, particularly in the selection, utilization, and interpretation of laboratory material. It is my purpose to discuss three outstanding instances of obsolete laboratory procedure and to suggest revisions in keeping with modern points of view.

The Skull

The traditional story of the general evolution of the skull runs briefly as follows. The primitive skull is considered to have been cartilaginous in composition. The shark is employed to illustrate this initial stage. Progressively, then, membranous bone encases the chondro-

cranium and the cartilage is replaced by bone. A urodele, Necturus or Cryptobranchus, customarily serves to illustrate an intermediate stage in this conversion, i.e., a cartilage, replacement bone, and membranous bone skull, and the mammalian skull the end point, i.e., the bony skull.

Modern paleontological data, in contrast to classical theory, strongly suggest that the original skeletal material was bone rather than cartilage. The cephalaspid Ostracoderms of late Silurian and early Devonian times not only possessed a superficial armor of bony plates but an ossified internal skeleton as well (Romer, 1942, 1945). It may be argued, of course, that these ancient forms may have been preceded by cartilaginous forebears unknown because cartilage is not fossilized. In rebuttal it may be pointed out that cartilage, then, must have occurred in very remote times for bony tissues featured the scantily known vertebrates of the Ordovician. More significantly, the view of progressive increase in bone and parallel decrease in cartilage which classical theory requires is not substantiated by fact. The later Ostracoderms, for example, show less bone than the older; in its history among the Ostracoderms bone is regressive, not progressive.

An especially clear demonstration of bone reduction is found in the Amphibia. Evans (1944), in reviewing the morphological status of modern Amphibia, has performed an important task in pointing out that modern Amphibia are highly specialized tetrapods and not primitive, a situation long recognized by paleontologists but apparently not so by many zoologists, especially writers of textbooks and laboratory manuals. Speaking of the skull alone, the total number of individual bones is much smaller than that of ancestral Amphibia, e.g., Eryops, and the amount of cartilage much greater. Furthermore, in comparing modern Amphibia and reptiles, Evans has clearly shown that in many respects some of the reptiles, e.g., Iguana, have departed less from the primitive tetrapod condition than have the Amphibia. Special advantage may be taken of this in a manner to be described shortly.

Now it is true that in its embryogeny the skull of a mammal, say, does begin as cartilage which progressively becomes bony by the replacement of cartilage and addition of dermal elements. But classical theory to the contrary, ontogeny by no means recapitulates phylogeny. Rather, the evolutionary history of the skull has been almost the reverse; the primitive condition is one of bony material and numerous separate elements. When the skulls of modern adult vertebrates consist of cartilage in whole or in part, it apparently represents a specialized condition wherein an embryonic adaptation is carried over into adult life (Romer, 1942).

To return to the matter of laboratory teaching, what we have been presenting in the laboratory through the customary shark-urodele-mammal series has not been phylogeny at all but ontogeny imitated by adult types. As indicated once before, any series derived from extant forms alone is necessarily artificial; the chosen forms only imitate, do not duplicate phylogenetic stages. This allows complete freedom of choice. The important thing is to select good imitators and arrange

them in the proper order. I should like to suggest the following series to illustrate the phylogeny of the skull.

1. *The skull of Amia, the bowfin.* It is chosen as the introductory form first because it is representative of a group which is relatively primitive and secondly, and more importantly, the elements of its skull have departed little from the fundamental pattern found in the Crossopterygii. The distinctive feature of the basic fish skull is the presence of an elaborate dermatocranium overlying a brain-enclosing endocranium. Amia is employed to illustrate this dermatocranium alone.

2. *The skull of Squalus, the shark.* A study of the skull of the shark serves two purposes: (a) without reference to its material composition, it exemplifies the basic pattern of the vertebrate endocranium; (b) in contrast to the skull of Amia, it illustrates a condition of degeneracy wherein cartilage is the structural material and a dermatocranium is lacking.

By way of the first two types listed, the fundamental pattern of the vertebrate skull is exemplified; that of the dermatocranium by Amia, the endocranium by Squalus. The history of the skull continues in the tetrapods.

The first tetrapods were amphibians which appeared in Devonian times and were derived from the Crossopterygii. The skulls of these original Amphibia were remarkably similar to those of their piscine ancestors. Modern Amphibia, as previously noted, however, have skeletons in which there are many specialized degenerate features. For that reason, no present-day amphibian will serve to exemplify the primitive tetrapod skull. We turn, instead, to the reptiles.

3. *The skull of the Alligator.* Although the reptiles as a group have been derived from and are thus more recent than the Amphibia, there are extant forms among them which, in respect to skeletal pattern, have departed much less widely from the primitive tetrapod condition than have extant amphibians. This is especially true of certain lizards, for example, Iguana. But since these lizards are not available in quantity, it is more practicable to employ the skull of the alligator. The alligator is somewhat specialized as regards the bones in the roof of the mouth, but otherwise serves as an excellent demonstration of the locations, groupings, and relations of the cranial and jaw bones of tetrapods.

4. *The skull of Necturus.* As pointed out before, modern amphibians although as a group phylogenetically older than the reptiles, are considerably specialized. The skull of the urodele, Necturus, demonstrates this specialization first in the retention of a considerable amount of cartilage within the endocranium and splanchnocranium and secondly, in a reduction in the absolute number of bones as compared with extinct primitive amphibians and many modern reptiles. One purpose, then, of a study of the skull of Necturus is to observe these specializations, i.e., to draw attention to the direction evolution has taken in Amphibia.

A second purpose is served by the hyobranchial apparatus. Although it, too, is somewhat specialized when compared with primitive Amphibia, compared with the reptiles it is much more primitive. It thus illustrates

a condition intermediate to the hyobranchial skeleton of Squalus, on the one hand, and that of reptiles and mammals on the other.

5. *The skull of the cat.* This traditionally employed form illustrates the pattern of the mammalian skull.

The Heart

The customery textbook account of the phylogeny of the heart is another which bears the imprint of the principle of recapitulation. In its embryogeny, the mammalian heart exhibits four chambers, sinus venosus, atrium, ventricle, and conus in that order from posterior to anterior. First the atrium is divided into two auricles and subsequently the ventricle into two. The conus is eliminated as such by being split into pulmonary and systemic trunks; the two sides of the sinus are eliminated by reduction and absorption. These steps are presumed to be paralleled phylogenetically: the heart of a fish corresponds to the primitive four-chamber stage, that of an amphibian presents the divided atrium, and the reptilian heart shows a progressively dividing ventricle. There is evidence to suggest, however, that this was not the phylogenetic order of events; to a degree, in fact, the reverse may have occurrd.

The key to the situation is found in the Crossopterygii, the group of fishes from which the original Amphibia, and thus tetrapods as a group, stemmed. Since, with the exception of one incompletely preserved specimen, these forms are known through fossil material only, direct knowledge of their soft anatomy is lacking But certain inferences can be drawn from a study of the internal anatomy of their nearest living relatives, the Dipnoi, or lungfishes

The heart of a representative lungfish exhibits extensive division into right and left sides The sinus venosus empties into the right side of the atrium which is divided almost completely by a muscular septum into larger right and smaller left auricular chambers. The ventricle, too, is incompletely divided by a conspicuous interventricular septum. A spiral septum divides the conus into two passageways, one of which communicates posteriorly with the left side of the ventricle and anteriorly with the first two aortic arches to the head; the other communicates with the right ventricle and the more posterior aortic arches including the pulmonary. Thus the cavity of the entire heart is incompletely but effectively divided longitudinally into two channels, with the arterial stream on the left driven to the head and the venous stream on the right driven to the lungs.

That the heart of the Crossopterygii was much like this is not unlikely. The presence of internal nares suggests the presence and utilization of an air-bladder like modern Dipnoi, and the rest follows logically. An ultimate answer must be deferred until that fortunate day when additional specimens are brought up from the depths of the South Atlantic.

If it may be granted that the Crossopterygii had some such heart as this, then it is not unlikely that so also did the original Amphibia. Truly enough, modern Amphibia exhibit no such condition, but it must be

remembered that living amphibians are highly specialized and this shows up in the heart as in so many other respects. In none of them is the ventricle divided. In the Anura the atrium is divided into two auricles, the right one receiving the sinus venosus. Leaving the undivided ventricle, blood is directed into separate pulmonary and carotid streams by way of a spiral septum within the conus. That much of the primitive subdivision, then, is retained. But in the Urodela, the separation is much less complete. While the sinus venosus, auricles, and ventricle resemble in general those of the Anura, the conus is usually much simpler. In the aquatic urodeles the spiral valve disappears more or less completely. The ultimate in degeneration is reached, indeed, in the aberrant lungless salamanders where not only is the conus undivided, but the interauricular septum is absent likewise. This represents a return to the original shark- or teleost-like condition.

I should like to suggest, then, that division of the chambers of the heart into right and left sides was accomplished as far back as the Crossopterygii and has been a feature of tetrapods in general since their origin; that modern Amphibia, with their incompletely divided hearts, illustrate a condition of degeneracy rather than one intermediate to fishes and amniotes as customarily taught. It would seem better, therefore, to limit laboratory studies to the heart of fishes and mammals. At least if the amphibian heart is studied, its position in the phylogenetic scheme of things should be clarified.

The Excretory System

The excretory organs of vertebrates consist of a large number of tubules which collect waste products and empty into a common drainage duct. Each tubule bears an intimate relation to the vascular system and ideally is in communication with the coelom. Comparative embryological data show that the tubules always are derived from the middlemost of the three divisions of embryonic mesoderm. The data also suggest that in the original vertebrates the kidneys extended the length of the coelom and were made up of segmentally arranged tubules, all alike and all open to the coelom. This hypothetical kidney has been designated an archinephros (holonephros) and its drainage duct the archinephric duct.

The tendency in modern vertebrates, however, has been for the tubules to exhibit increasing complexity from anterior to posterior. In fact, in amniote embryos all levels of the kidney forming tissues do not differentiate at the same time; rather they appear to develop in three groups, one behind the other both in time and space. These constitute, respectively, the pronephros, mesonephros, and metanephros. Although somewhat beside the point of this discussion, it is not amiss to point out, however, that distinctions made between these three groups of tubules have been unduly emphasized. It is always difficult to say where one group of tubules ends and the other begins; one grades imperceptibly into the other (Torrey, 1943). Further, modern experimental studies show that given certain circumstances, mesonephrogenic tissues may

form either pro- or metanephros. Such facts can only mean that the intermediate mesoderm is empowered to produce *a* kidney, not three. Originally all the tubules were alike, but conditions in the internal environment have led to progressive structural complexity. To put it another way, the intermediate mesoderm is competent to produce kidney tubules in a generic sense; the specific kind of tubule depends upon internal circumstances along the length of the body.

To return to the main theme, it is customarily said that in its evolutionary history the kidney parallels its ontogenetic history in amniotes. Accordingly, the myxinoid cyclostomes are described as having a pronephros and the fishes and amphibia as having a mesonephros (preceded by the embryonically provisional pronephros). As a matter of fact, the myxinoids come pretty close to presenting the ideal vertebrate archinephros. The myxinoid kidney extends the length of the coelom, that is, involves essentially all the nephrogenic mesoderm, and, except for the last few, the tubules are of the simplest grade. In terms of tubule structure it is a pronephros; but topographically it includes mesonephrogenic and metanephrogenic areas as well as pronephric. It is not the equivalent of the amniote pronephros at all; it is the spatial equivalent of all three amniote kidneys except that its tubules have attained only the pronephric grade of differentiation.

A similar situation prevails in the case of the so-called mesonephros of the adult fish or amphibian. The anterior end of the nephrogenic mesoderm differentiates into the pronephric grade and, with certain few exceptions, this pronephros disappears. The remainder, meaning the material which in amniotes will produce meso- and metanephros, then attains the mesonephric level of development. In terms of tubule structure it is a mesonephros; but in spatial terms it corresponds to both the meso- and metanephros of amniotes. It is not, therefore, the equivalent of the amniote mesonephros. Along with Miss Hyman, who has done so in the 1942 revision of her popular text and laboratory guide, I would favor the use of Graham Kerr's term opisthonephros to describe the adult kidney of fishes and amphibians.

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INDEX

Action potential measurements and visual stimuli, 170.
Adams, William Richard, 16.
Adena culture, at the Cato Site, 18.
Agar, decomposition of, 34.
Agriculture, on American forest frontier, 92.
Akeley, E. S., 164.
Allen, William A., 65.
American forests, factors in settlement of, 92.
Anderson, D. J., 182.
Andes, agricultural problems, 38.
Anthropology abstract, 15.
Anthropology, section on, 15.
Archaeological survey, Martin County, 16.
Archaic culture in New York, 18.
Atomic beam, use of in spectroscopy, 166.
Auditing committee, report, viii.

Bacteriology abstracts, 33.
Bacteriology, section on, 33.
Bastioned stockades, aboriginal in North America, 15.
Beckman, Robert D., 164.
Biological survey, report, ix.
Biology and the post-war world, 8.
Black, Glenn A., 18.
Bog, cabin creek, 37.
Bonding Committee, report, ix.
Botany abstracts, 36.
Botany, section on, 36.
Breccias, produced from chemical weathering, 107.
Breneman, W. R., 182, 185.
Bruner, Henry Lane, 1.
Buddha outlier of the Mansfield sandstone Lawrence County, Indiana, 96.
Budget Committee, vi.
Burr, Irving W., 163.

Cabin creek, bog, 37.
Calcitic pisolites, forming in travertine, 102.
Campeloma sp. intermediate host of *Neoechinorhynchus emydis*, 183.
Cataract Falls sandstone of the Ste. Genevieve formation in Southwestern Indiana, 77.
Cato Site, Pike County, Indiana, 18.
Cercaria, life history of a giant cystocercous, 183.
Cercaria szidati, life history of, 182.
Chara brittoni, in Indiana, 37.
Chemistry, section on, 65.
Chen, K. K., 190.
Cleland, Ralph E., 36.
Cole, Versa V., 33.
Committees for 1945, v.
Coon, Jesse B., 164.
Corn, a primitive characteristic in, 38.

Deam, Charles C., 50.
Deese, James, 171.
Degering, Ed. F., 65, 69.
Denuyl, Daniel, 36.
Dichotomous key to the species of the genus bacillus, 33.
Dirca palustris, growth of an injured plant of, 48.
Distribution records, plant, 50.
Divisional chairmen, v.
Dowell, L. G., 165.
Dragonflies, of Tippecanoe River State Park, Pulaski County, 196.

Editor and publication of Proceedings, ix
Edmondson, Clarence Edmund, 3.
Electron accelerator, theoretical calculations regarding, 164.
Electron-diffraction study of the "polish layer," 165.
Embryological formulas in plant taxonomy, 37.
Entomologists meeting, xiv.
Erselcuk, Muzaffer, 78.
Executive Committee, v.

Fifty-year index, report, ix.
Fifty-year index, committee, vi.
Focussing of ions in a magnetic field, 167.
Foley, Arthur Lee, 4.
Forests, factors making settlement possible, 92.
Forest trees, planting in Indiana, 36.
Freeman, Otis W., 83.
Friesner, Ray C., 37, 50.

Gas gangrene, factors, influencing death from, 33.
Geography, secondary school, 89.
Geologic contrasts in Indiana State Parks, 83.
Geology and Geography, abstracts, 77.
Geology and Geography, section on, 77.
Girton, Raymond E., 39.

Gonad stimulating hormones, 182.
Goniobasis livescens host of a giant cystocercous cercaria, 183.
Guard, A. T., 46.

Hamsters blood, cellular constituents and chemistry of, 190.
Hannah, J. R., 190.
Harrison, Benjamin, memorial, resolution, xi.
Higinbotham, Noe, 37.
History, Biology, University of Notre Dame, 147.
History of Science, section on, 147.
Hopewellian culture, at the Cato Site, 18.
Hopp, W. B., 183.
Householder, J. C., 23.
Hufford, Mason E., 165.
Hulpieu, H. R., 33.

Indiana Historical Society, Cato Site collection acquired by, 18.
Indiana plant distribution records, VI. 1945, 50.
Indiana scientists, age, birthplaces, collegiate training, distribution, doctoral training, specialities, 154.
Indiana seasons beginning dates, 144.
Indiana, State Parks of, geologic contrasts in, 83.
Influenza virus vaccine for general use, 33.
Iron and steel industries of Manchuria, 78.

Jennings County, ecological study of the Kleine Woods, 38.
Jet propulsion, 164.
Junior Academy of Science Officers, xvii.
Junior Academy of Science, report, x.
Junior Academy, member clubs, xxiii.
Junior Academy minutes, xx.
Junior Academy program, xix.
Just, Theodor, 37, 147.

Karst features, Maya region of Yucatan, 111.
Kellert, Carl O., 38.
Kelley, Mary Frances, 15.
Kellogg, W. N., 171.
Ketene, synthesis and reactions, 69.
Koch, G. David, 89.
Kriebel, Ralph, 50.

Lark-Horovitz, K., 165.
Learning, rote, 178.
Liaptcheff, K. K., 183.
Library committee, report of, ix.
Lillard, Richard G., 92.
Livingston, William Arnold, 170.
Loew, Fred A., 48.

Malott, Clyde A., 77, 96.
Manchuria, iron and steel industries of, 78.
Markle, Millard S., 8.
Martin County, a preliminary report on, 16.
Mathematics, abstracts, 163.
Maya region of Yucatan, karst features in, 111.
Membership, report, x.
Mench, J. W., 69.
Minutes of Executive Committee, viii.
Minutes of General Session, xiii.
Mundie, L. G., 166.
Murray, F. J., 34.

Natural history of Indiana, social behavior of animals, 183.
Necrology, 1.
Neoechinorhynchus cylindratus, life history of, 183.
Neumann, Georg, 26.
Newcomb, Margaret, 36.
New members, 1945, xv.
New members, additional 1944, xv.
Nitrogen Dioxide oxidation of starch, 69.
Nominations, x.
Notre Dame, University of, history of department of Biology, 147.

Odonata, of Tippecanoe River State Park, Pulaski County, 196.
Oenothera plants from embryos cultured in vitro, 36.
Oenothera, cultivation of excised embryos, 36.
Officers for 1945, v.
Orndoff, J. D., 165.

Palmer, C. M., 33.
Passamaquoddy and Quapaw mnemonic records, 29.
Pepper, Paul M., 163.
Perceptual span and rate of reading, 170.
Peru, corn in, 38.
Phylogenetic interpretations, in teaching comparative anatomy, 206.
Physical types of American Indian, 26.
Physics, abstracts, 164.
Physics, section on, 164.
Pike County, archaeological site in, 18.
Porter, C. L., 38.
Post-war world, biology and, 8.
Potzger, John E., 37.
Powell, H. M., 33.
Presidential address, 8.

Press Secretary, report, x.
Psychology abstracts, 170.
Psychology, section on, 170.
Pulaski County, Odonata of Tippecanoe River State Park, 196.
"Punch-card" method for the identification of gilled mushrooms, 38.

Quapaw mnemonic records, 168.

Radiation from electron, 168.
Ramsey, R. R., 168.
Randolph county, bog, 37.
Reflex behavior modification of, in spinal dogs, 171.
Refractions in a compound lens, 165.
Relation of Academy to A.A.A.S., report, x.
Relation of Academy to State, report, x.
Reminiscence, in rote nonsense syllable learning, 178.
Renzema, T. S., 165.
Research Grant, committee, ix.
Respiration of seed plants, 39.
Retention, short time intervals, 178.
Roller, Duane, 167.
Rose, C. L., 190.

Sand, 121.
Scanlon, Wayne, 167.
Schwarz, W. M., 167.
Scientists, of Indiana, a statistical study, 154.
Scott, Donald C., 196.
Seitner, P. G., 183.
Shell mound complex, at the Cato Site, 18.
Shoshonean Indian types, 26.
Shrock, Robert R., 102, 107, 111, 117.
Significance of symbols in physical equations, 167.
Smith, Ernest Rice, 121.
Spectograph, two meter grating, 164.
Spectroscopic analysis of potassium-sodium solution, 167.
Standing committees, vi.
Starch, nitrogen dioxide oxidation of, 69.
State Flora Committee, 50.
Statistical methods for controlling the quality of industrial products, 163.
Stone, G. R., 178.
Structure of tellurium as a function of temperature, 165.
Sutherland, Jean, 170.
Symmetry in metric spaces, 163.

Table of contents, iii.
Taxonomists meeting, xiv.
Tellurium, structure as a function of temperature, 165.
Temperature, structure of tellurium as a function of, 165.
Tippecanoe River State Park, Odonata of, 196.
Tomato, abnormal fruit character in, 46.
Torrey, T. W., 206.
Trace element deficiencies in rice, 37.
Travel in primeval American forest, 92.
Travertine deposits, pisolites forming in, 102.
Treasurers report, viii.
Trustee, report of Academy, viii.

Urinary gonadotropins in normal men, 185.
Virginia's Indian neighbors in 1712, 23.
Visher, Stephen S., 144, 154.
Vogel, Howard H., Jr., 183.
Volcan Paricutin, sedimentation and wind action around, 117.

Warnock, Clarence O., 7.
Weatherwax, Paul, 38.
Weed, L. A., 33.
Weer, Paul, 29.
White River Valley, archeological survey, 16.
Woodlands culture, at the Cato Site, 18.

Yucatan, karst features in Maya region, 111.
Yuncker, T. G., 50.

Zabel, H. E., 154.
Zoology abstracts, 182.
Zoology, section on, 182.